THE TISSUES AND THEIR STRUCTURE

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A DESCRIPTION OF THE

ELEMENTARY TISSUES OF THE HUMAN BODY.

BY

ALEXANDER S. KENNY, M.R.C.S.E.

SENIOR DEMONSTRATOR OF ANATOMY AT KING'S COLLEGE,

LONDON.

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PREFACE.

MY object in this work is to provide for the use of students a concise description of the structure and functions of the elementary tissues. I trust that, beside being serviceable to those who are preparing for examination, it may also be a useful adjunct to the Practical Physiology class, enabling those who use it to obtain a clear conception of the general structure and functions of those tissues with the histological manipulation and preparation of which they are at the same time becoming familiar. I have endeavoured to avoid unnecessary discussion, only putting forward those views which are most generally accepted. For the study of the more minute histological details, the

student is referred to the larger text-books, as Quain's *Anatomy* and Carpenter's *Physiology*, to which works, among many others, I have to acknowledge my indebtedness.

With the exception of the diagrammatic representation of nerve-endings in Plate VI., and one or two others, the source of which has been acknowledged, all the illustrations are taken from specimens in my possession.

LONDON,
April 22nd, 1882.

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THE TISSUES AND THEIR STRUCTURE.

CHAPTER I.

Origin of the Tissues—Animal and Vegetable Cells—Production of Cells—Protoplasm—Classification of Tissues.

IN beginning a description of the structure of the tissues of organized bodies, we may, without entering into any unnecessary discussion, state, that the result of research in the past has been to show that the various tissues and structures met with in plants and animals, however complex and differentiated they may ultimately become, originate, one and all, by means of elementary corpuscles, which have been named *cells*. These cells are capable of undergoing certain transformations, according to the conditions under which they are placed, and the functions they have

to perform. They remain separate in the fluids, but are usually grouped together in the solids. In some cases they undergo but little change, while in others, becoming differentiated to a greater or less degree, they produce the various modifications of form and structure met with in the animal and vegetable textures.

The cells of the early embryo of plants consist of,—

1. An external investing envelope or membrane—the *cell-wall.*

2. Within this a semi-fluid granular material—the *protoplasm* or *cell contents.*

3. Imbedded in this a more sharply defined body—the nucleus, which differs from the surrounding protoplasm in not being contractile.

4. Occupying the interior of the nucleus may be observed one, or sometimes more, distinct refracting particles—the *nucleoli.*

The cells of the animal embryo consist of a granular, protoplasmic substance inclosing a nucleus, which, in turn, contains one or more nucleoli. From this description it will be seen that there is a distinct difference

between an animal and vegetable cell; since the vegetable cell has a cell-wall, while the animal cell has none. An animal cell may, therefore, be defined as 'a mass of protoplasm possessing a nucleus and sometimes a nucleolus.'

PRODUCTION OF ELEMENTARY CELLS.

It was Schwann who first made the important general statement, that all the tissues of the animal body were composed of or derived from cells. The cells of the animal body are derived from the fertilised ovum. The mammalian ovum differs from the elementary cells already described in possessing a distinct cell-wall, which is called the *Zona pellucida*, or *vitelline membrane;* but it resembles them in being composed chiefly of a granular, protoplasmic material, the *yelk*, within which again is the *germinal vesicle* and *germinal spot*, which correspond respectively to the nucleus and nucleolus of the ordinary elementary cell. The elementary or embryonic cells are produced from the fertilised ovum by a process of cleavage or segmentation. The germinal vesicle and germinal spot disappears, and the protoplasmic material, shrinking slightly,

divides into two equal parts. These segments subsequently divide into two, and this division, in multiple proportion, continues until the entire yelk is split into a number of small segments, each consisting of protoplasmic material and possessing a nucleus. In this way the ovum is the parent of all the new cells which are formed within it, and the progenitor of all the cells which are descended from those which result from the segmentation of the yelk.

The following is a brief outline of the various forms of cell genesis :—

1. *Fission.*—In this form of development a cell becomes constricted, and, owing to the gradual deepening of the constriction, subdivides into two parts, the nucleus also participating in the subdivision.

2. *Budding.*—When the multiplication takes place by budding, little processes of protoplasm bud out from the parent cell, and, subsequently becoming detached, assume an independent existence.

3. *Endogenous reproduction* is a form of internal budding, by which the young cells are developed within the parent cell till the

original cell is broken up. This last form is well exemplified in the production of the elementary cells from the ovum in the manner described above.

PROTOPLASM.

The basis of vital activity; is a complex substance, from which can be obtained, by analysis, examples of the albuminous, fatty, and starchy groups, with a variable quantity of salts. It is usually viscid, varying much in consistency,—sometimes being semi-fluid, at other times being an exceedingly viscid, coherent material. When exposed to a temperature of about 130° F. it undergoes heat-stiffening and dies, undergoing a kind of coagulation. Protoplasm is met with in many varied forms; it occurs inclosed in tubular sheaths (as in muscle), or as granular masses of variable form (cells) with nuclei. Such contractile masses form the whole substance of the body of many of the lower forms of animal life, as the Amœba, or the soft portions of other animals. It occurs in colourless blood-corpuscles, and also in the analogous corpuscles of areolar tissue, in the lymph corpuscles, and in mucus and pus in the higher animals.

The way in which cells are associated together to form different tissues and substances depends to a great extent upon the matrix or intercellular substance, and upon the relation the cells bear to it.

1. The intercellular substance may be fluid, as in *blood*, which may be regarded as the simplest form of tissue.

2. It may consist of a soft, semi-gelatinous material, as in *mucous* tissue.

3. It may be firm and solid, as in *cartilage* or *bone.*

4. Lastly, it may be very slight in amount, as in *epithelium*, where it seems merely to cement the cells together.

The tissues of the human body have been divided, according to their functions, into two great classes; namely, those which have some active, vital function to perform, and those whose function in the organism is of a purely passive nature, and which serve to connect and support the various parts of the body. Those tissues which belong to the former class are called *active* tissues, and those belonging to the latter class are called *passive* tissues. The tissues which belong to the two

lasses respectively may be set down in the ollowing order :—

PASSIVE TISSUES.

1. Mucous.
2. Retiform or Adenoid.
3. White Fibrous.
4. Yellow Elastic.
5. Areolar.
6. Fat.
7. Cartilage.
8. Bone.
9. Tooth.

ACTIVE TISSUES.

1. Nerve.
2. Muscle.
3. Epithelium.

CHAPTER II.

PASSIVE TISSUES.

Mucous Tissue—Retiform, White Fibrous, Yellow Elastic, Areolar Tissues—and Fat.

1. MUCOUS TISSUE.

This tissue, when examined under the microscope, is seen to consist of stellate protoplasmic cells, which possess processes that unite with one another, and are imbedded in a clear, semi-fluid matrix. In the human body it is met with in the jelly of Wharton in the fœtus, and in the vitreous humour of the eye; that in the vitreous humour is modified in structure, most of the bodies of the cells have disappeared, their processes alone remaining dispersed throughout the matrix. It also occurs in many parts of the embryo.

2. ADENOID OR RETIFORM TISSUE.

This tissue has also been called *reticular* and *glandular* tissue. It consists of stellate cells, whose processes unite; the interstices between

the cells being filled up with glandular material, as in the spleen pulp, or with cells, as in lymphoid tissue. A very fine variety of this tissue is met with in the spinal cord and brain, passing in between the bundles of nerve fibres, and supporting them; it is called *neuroglia.*

3. WHITE FIBROUS TISSUE.

Microscopical Appearances.—When examined under the microscope this tissue is seen to consist of fibres which have an ill-defined, wavy outline, and are usually parallel to one another. These fibres do not anastomose, and do not curl up at their ends (P. I. Fig. 3). They are very frequently bound together to make bundles, and in these bundles, oval, branched cells may occasionally be seen. These cells are similar in almost every respect to the ordinary stellate corpuscles, which are met with for the most part throughout the whole of the passive tissue group. They possess a delicate protoplasmic body, which is thick in the centre but bevelled off towards the sides, and contain a round or oval nucleus with several nucleoli.

Properties.—This tissue is tough, inelastic,

strong, and unyielding. It swells up and dissolves on the addition of weak acids, and yields *gelatin* on boiling.

Uses of white fibrous tissue;

It forms ligaments, tendons, and aponeuroses for the attachment of muscles. It occurs, also, in supporting capsules, of which the best examples are the *tunica albuginea* of the testicle and the sclerotic coat of the eye. It enters into the formation of the external coat of large arteries, where it serves to protect them and to prevent their over-distention. Lastly, it enters largely into the formation of fascia, and forms a constituent part of areolar tissue.

4. YELLOW ELASTIC TISSUE.

Microscopical Appearances.—It consists of fibres which have a hard, well-defined outline, and which anastomose freely, and curl up at their ends (P. I. Fig. 2).

Properties.—It is elastic and yielding, it is not affected by weak acids, and yields *elastin* on boiling.

Uses.—It is useful in forming ligaments where adaptability is required, as, for instance, in the *ligamenta subflava*, in the true vocal

cords, and the suspensory ligament of the penis. It forms a part of the middle coat of blood-vessels, where it is of use in converting a jetting stream into a continuous flow. It is useful in the lungs, allowing for their expansion and recoil during respiration. It is found in the capsule of the spleen, where it permits of the enlargement of the gland, which occurs during digestion, and adapts itself to the diminished size of the gland when digestion is completed. Lastly, it is found throughout the skin generally, where it is of use in allowing it to stretch and to adapt itself to the various movements of the body. Finally, together with white fibrous tissue, it enters into the formation of areolar tissue.

5. AREOLAR TISSUE.

Microscopical Appearances.—If a portion of areolar tissue is examined under the microscope it is seen to consist of yellow elastic, and white fibres, which are associated together to form bundles, which cross and recross in all directions. Though the bundles of fibres thus freely interlace, the individual fibres of the bundles are, in most instances, parallel to one another. Between the bundles there is a cer-

tain amount of granular ground substance which seems to cement them together; and in this are situate numerous stellate protoplasmic cells, which send their processes into the bundles of fibres.

Blood-vessels traverse the tissue on their way to other parts, but only a few have been seen to terminate in it.

Nerves also, in like manner, pass through it, but have not been seen to end in it.

Lymphatics.—A close connexion exists between the cells of areolar tissue and the commencement of the lymphatics; for the flattened cells, which enter into the formation of the walls of the lymphatic vessels, become continuous with the processes of the stellate cells of the areolar tissue.

Thus the lymphatics may be said to take origin, as it were, in a network from the cell spaces of the tissue. Absorption by the lymphatics readily takes place from these spaces.

Not only do large lymphatics traverse this tissue on their way to or from distant parts, but in many cases large lymphatic networks may be observed beneath the skin, and beneath mucous and serous membranes.

Properties.—It is resilient and elastic, possesses no sensibility, and is only sparingly supplied with blood-vessels; a considerable quantity of water enters into its composition, so that it loses much of its weight on drying. When boiled it yields a large quantity of gelatin, and after a prolonged boiling a slight amount of elastin. The addition of acetic acid causes the white fibrous portion of it to swell up and dissolve, rendering the elastic element still more apparent.

Uses.—Areolar tissue is one of the most extensively distributed tissues in the body, and many varieties of it have been distinguished. When placed, for instance, beneath the skin, or beneath mucous and serous membranes, it is simply designated according to the membrane beneath which it is placed—*subcutaneous*, *submucous*, or *subserous* areolar tissue. When placed between muscles and vessels, and other organs uniting and connecting them together, it is called *intermediate* areolar tissue. In many cases it becomes more dense and consistent in its nature, forming a kind of sheath for muscles or glands or other organs, it is then called *investing* areolar

tissue. It is often found passing in between the fibres and fasciculi of muscles, uniting them together; and also binding together the lobes and lobules of glands. It follows the ramifications of blood-vessels and nerves within these organs, supporting and protecting them. To this variety the name of *penetrating* areolar tissue has been given. The fact of its extensive distribution and continuity throughout the body is of considerable medical interest, offering, as it does, an explanation of the means by which urine, dropsical waters, blood, or even air, effused into the areolar tissue spaces, may make their way from the spot where they were first effused to some distant part of the body.

6. FAT TISSUE.

Microscopical Appearances.—When examined under the microscope fat or adipose tissue is seen to consist of small vesicles, which have a dark refracting outline filled with oily material, and enclosed in the meshes of areolar tissue. These vesicles are in some instances individually separated from one another, while in others they are collected into lobular clusters; these, in turn, are associated together so

as to form little lumps of fat, readily visible to the naked eye, and these again are in some parts aggregated together to form irregular masses of considerable size (P. III. Fig. 2). The fat cells are usually round or oval, but when closely packed together their shape may be variously modified.

The size of the fat cells varies considerably, but their average size is about $\frac{1}{500}$th of an inch in diameter. Each cell possesses a delicate envelope, which is lined by a layer of protoplasm in which a nucleus with several nucleoli is imbedded, and which surrounds a clear, transparent, highly refracting drop of oil. In many cases the nucleus is not readily observable, as it is pushed aside and obscured by the fatty matter. Fat tissue is very freely supplied with blood-vessels. Comparatively large vessels are distributed to the lumps of fat, and these running between the lobules divide and subdivide, till at last a small artery and vein pass to each lobule, where, becoming much diminished in size and undergoing still more minute division, they surround the cluster with a minute capillary plexus externally, and then pass in between

the vesicles in all directions, supporting and connecting them. The lymphatics of fat are said to form wide meshed capillary plexuses; but beyond the fact that they bear an intimate relation to the blood-vessels—indeed, in many cases they are peri-vascular,—but little is known of their arrangement and distribution in this tissue. No nerves have been seen to end in adipose tissue, but nerves destined for other parts pass between its lobules.

Properties and Composition.—Human fat is composed chiefly of *palmitin*, *stearin*, and *olein*. These (which are the saponifiable or neutral fats) are formed by the union of a fatty acid radical with glycerine in the proportion of three to one; they are therefore called *tri*-palmitin, *tri*-stearin, and *tri*-olein. Tri-olein forms about one fourth of the fat of the body, and is the liquid or oily constituent, holding in solution the other two (tri-palmitin and tri-stearin) which constitute the remaining three-fourths, and are the solid ingredients.

The varying consistency of animal fats depends upon the relative proportion of the

solid and liquid ingredients. The neutral fats are insoluble in cold water, but readily soluble in hot alcohol, fluid oils, ether, benzol, carbon disulphide, and chloroform. Treated with alkalies they are saponified; that is, the fat is decomposed into fatty acid and glycerine, the fatty acid uniting with the alkali to form a soap whilst the glycerine remains in solution. They form an emulsion with a solution of albumin, and are highly inflammable. *Cholesterin*, which is a constituent of fat, can be obtained from nearly all the tissues and fluids of the body and occurs in gallstones, and the fluid of some hydatid and ovarian cysts. Cholesterin is not decomposed when treated with alkaline solutions. It is lighter than water, and is not dissolved by it; it is very soluble in ether. It gives a deep red colour when evaporated with nitric acid, and the residue is touched with ammonia, and a violet colour when evaporated with hydrochloric acid and ferric chloride. The amount of fat in the human subject is about $\frac{1}{20}$th of the weight of the body, but it is liable to great variations.

Uses.—(1.) It maintains the temperature of

the body in two ways. (*a.*) Because it is a heat-producer—that is, being composed chiefly of carbon and hydrogen, it combines with oxygen to form carbonic acid and water, thus contributing to the heat of the body. (*b.*) Because it is a bad conductor of heat, and so helps to retain the warmth within the body.

(2.) It is a packing material, filling up inequalities and forming a bed in which other structures can lie.

(3.) It is protective, being deposited around and between different organs, affording them support, facilitating motion, and protecting them from the injurious effects of pressure. As examples of this last use may be mentioned the existence of fat in the palms of the hands and soles of the feet, in the orbits, and around the kidneys. When the digestive process introduces into the system more carbon and hydrogen than is required for immediate consumption, the excess of these elements is stored up in the form of fat, to be reabsorbed when required. The use of fat in nutrition is well illustrated in hybernating animals.

Though the chief source of fat in the body is the oleaginous constituents of the food, it is also formed by the decomposition of saccharine and albuminous principles, which yield fatty acids, and, combining probably with glycerine, are converted into fat before their ultimate reduction into carbonic acid and water.

Where found.

1. Beneath the skin generally.
2. In the great omentum, mesentery, &c.
3. Lying on the outer surface of the synovial membranes, and filling up inequalities in joints.

Absent from.

1. The eyelids.
2. The penis.
3. The scrotum.
4. The lungs.

Fat tissue is also absent from the cranial cavity.

As under normal conditions fat is decomposed into carbonic acid and water in the body, only minute quantities are met with in the healthy human excretions. Under abnormal conditions, however, fat appears in

the excretions; when, for instance, the pancreatic and biliary ducts are occluded, the fats introduced with the food into the intestinal canal are not emulsified and saponified, and, remaining in consequence unabsorbed, pass unaltered out of the system with the fæces.

In chyluria, also, fat globules are seen in the urine.

CHAPTER III.

Classification of Cartilage—Temporary Hyaline Cartilage—Articular, Costal, White and Yellow Fibrous Cartilages—Physical and Chemical composition of Cartilages—*Chondrin*, *Gelatin*, and *Elastin* contrasted.

7. CARTILAGE.

1. Temporary—
   - A. Cellular.
   - B. Hyaline.
2. Permanent—
   1. Cellular (not present in man).
   2. Hyaline—
      - (i.) Articular;
      - (ii.) Costal.
   3. Fibrous—
      - (*a.*) White fibro-cartilage—
        - (i.) Interarticular;
        - (ii.) Connecting;
        - (iii.) Marginal;
        - (iv.) Sesamoid.
      - (*b.*) Yellow fibro-cartilage.

1. TEMPORARY CARTILAGE.

The term temporary cartilage is applied to that form of cartilage which exists in consider-

able quantity in the fœtus, and is subsequently converted into bone. Two varieties of it exist, the cellular and the hyaline.

A. *Cellular Cartilage* is so called because, when examined under the microscope, it is seen to consist of numbers of small, more or less spherical, granular-looking cells, closely packed together. The matrix, which varies greatly in amount, consists of very fine fibres, which pervade the tissue throughout, passing between the cells in all directions, and enclosing them in a network. Cellular or, as it has been called, parenchymatous cartilage, is met with in the chorda dorsalis of the fœtus, and it may also be readily obtained from the external ear of rats and mice.

B. *Hyaline Cartilage.*—When a thin slice of cartilage is examined under the microscope, it is seen to consist of nucleated cells imbedded in a solid matrix. Sometimes the matrix is dim and granular, like ground glass; while at other times it is clear and transparent. In hyaline cartilage, which is the typical form of the tissue, both these conditions occur. The cells of hyaline cartilage are masses of protoplasm, round or

oval in shape, possessing a well-marked nucleus and one or more nucleoli (P. II. Fig. 5). They are contained in cavities in the matrix named chondroplasts, which, under normal conditions, they completely fill. This cavity is lined by a fine transparent envelope which surrounds the cell, separates it from the matrix, and often presents concentric layers. In the temporary form of hyaline cartilage, the cells are evenly dispersed throughout the matrix; but in the costal and articular varieties they are usually arranged in groups. All cartilages, except those which occur in joints, are invested by a tough, fibro-vascular membrane called the *perichondrium.* When the cartilage becomes converted into bone, its membrane constitutes the periosteum, vessels ramify and freely divide and subdivide within it, but none have been seen to enter the cartilaginous substance till ossification begins, the cartilage itself receiving its nutrition from the vascular perichondrium by a process of imbibition.

2. PERMANENT CARTILAGES.

A. *Cellular.*—This variety does not exist in its permanent form in the human subject.

B. *Hyaline Cartilage.*—There are two varieties of permanent hyaline cartilage, the *articular* and the *costal.*

(i.) *Articular Cartilage.*—The matrix of articular cartilage differs from that of temporary hyaline cartilage, in that it is usually dim and granular. The cells are arranged in groups, but these are more regularly dispersed throughout the matrix than those which are met with in the costal variety of hyaline cartilage. If a vertical section of articular cartilage is examined, the groups of cells will be seen to have a very definite arrangement. Those placed nearest the bone are arranged in parallel rows, perpendicular to the surface of the bone they cover; but the more superficial groups of cells are flattened, closely packed together, and are parallel to the surface. The matrix of articular cartilage is scarcely ever pervaded by fibres like those often seen in costal cartilage, nor is it prone to ossify. This variety of cartilage is found covering the articular surfaces of bones.

(ii.) *Costal Cartilage.*—In costal cartilage, the matrix is tolerably clear, except when fibres have been developed in it, in which

parts it is opaque and yellowish. The cells of costal cartilage are longer than those of the articular variety, and the groups which they form are less evenly dispersed throughout the matrix. Many of the cells contain drops of oil in their interior; and the nucleus, which cannot usually be seen, is concealed by the fatty matter, or may itself have undergone fatty change. Costal cartilage has a great tendency to ossify. The cartilages of the nose, the ensiform cartilage, and the cartilages of the larynx, trachea, and large bronchi, with the exception of the cornicula laryngis, the cuneiform cartilages, and the epiglottis, closely resemble the costal cartilages in their minute structure; and with the exception of the cartilages of the nose, they resemble them in their tendency to ossify.

Vascular Supply.—The articular cartilages being destitute of perichondrium, derive their nutrition from the adjacent vascular structures, more especially the bone, by a process of imbibition. Where the cartilage exists in thick masses, as in the costal cartilages, channels are formed in it into which vessels

dip down to supply the deeper parts of the tissue, which are too distant to receive proper nourishment from the vessels of the perichondrium. These vessels, however, do not quit the vascular channels to ramify in the cartilaginous substance, so that it may still be regarded as extra-vascular. Cartilages are destitute of nerves, and are therefore devoid of sensibility.

C. *Fibrous Cartilages.*—(*a.*) *White fibro-cartilage* consists of cartilage cells which are imbedded in a matrix of ordinary white fibrous tissue. In some cases the fibrous matrix exists in great quantities, and the cells are comparatively few in number when we have a tough, unyielding cartilage, as in the semilunar cartilages of the knee-joint; in the others, the cells preponderate, and the cartilage is then soft and gelatinous, as in the central part of the intervertebral discs. White fibro-cartilage presents several varieties, which may be arranged in the following order:—

(i.) *Connecting.* (ii.) *Interarticular.*
(iii.) *Marginal.* (iv.) *Sesamoid.*

The sesamoid cartilages subsequently ossify.

(i.) *Connecting* fibro-cartilages are such as pass between the adjacent surfaces of bones in joints which do not admit of gliding motion. They exist in the following positions :—

1. Between the bodies of the *vertebræ.*
2. In the *sacro-iliac* articulation.
3. In the *symphysis pubis.*

(ii.) *Interarticular* fibro-cartilages are placed between the articular surfaces of bones, and exist in the following places :—

1. In the *semilunar cartilages* of the knee-joint.
2. In the *triangular fibro-cartilage* of the wrist.
3. In the *temporo-maxillary* articulation.
4. In the *sterno-clavicular* articulation.
5. In the *acromio-clavicular* articulation.

(iii.) *Marginal* or circumferential cartilages are such as deepen the articular cavities of bones, and exist as under :—

1. In the *cotyloid* cavity.
2. In the *glenoid* cavity.

(iv.) *Sesamoid* fibro-cartilages are found in the sheaths of tendons, and sometimes in their substance, as for instance—

1. In the *tibialis posticus.*
2. In the *peroneus longus.*

(*b.*) *Yellow fibro-cartilage* consists of cells with well-marked nuclei and nucleoli placed in a matrix, which is composed almost entirely of fine elastic fibres, and a small and variable quantity of hyaline, intercellular substance is also usually present. It is more flexible and tough than ordinary cartilage, and has but little tendency to ossify. It is found in the following places :—

1. Epiglottis.
2. Cornicula laryngis.
3. The cuneiform cartilages.
4. The cartilages of the ear.

The cartilages of the external ear essentially belong to the yellow fibro-cartilage group. The cartilage is invested by a perichondrium, which is plentifully supplied with yellow elastic fibres ; these penetrating the matrix of the cartilage, intercommunicate with one another, forming fine plexuses, in the meshes of which small cartilage cells are embedded. The cartilage of the Eustachian tube belongs, according to Kölliker, to the group of hyaline cartilages. The hyaline matrix frequently

containing fibres, includes groups of oval and rounded cartilage cells. As the cells near the surface they become gradually smaller, and there is here a layer of closely felted nucleated areolar tissue which represents the perichondrium. The cartilaginous substance and the perichondrium, present no distinct line of separation, but pass gradually one into the other; but here and there the vascular tissue of the perichondrium dips down more or less deeply into the substance of the cartilage (Stricker).

Composition of Cartilage.

When permanent cartilage is boiled for a long time, it is resolved into *chondrin.* This substance appears to be a modification of gelatine, but differs from it in that it is precipitated by acetic acid, the precipitate being soluble in potassium ferro- and ferricyanide, which distinguishes it from albumen. It is also precipitated by dilute mineral acids, and by the salts of aluminium, iron, lead, silver, and copper, whilst its solutions are only rendered slightly turbid by tannic acid.

Gelatin is transparent and colourless, and destitute of taste and smell. Solutions of it

are precipitated by alcohol and ether, but not by acids, with the exception of tannic acid. Chlorine water and corrosive sublimate precipitate it, but other salts of mercury and those of silver have no such effect upon it.

Elastin is the base of elastic tissue, and may be obtained pure from the ligamentum nuchæ of animals by boiling it successively with alcohol, ether, water, concentrated acetic acid, dilute solutions of potash, and hydrochloric acid (Carpenter).

CHAPTER IV.

Microscopical Appearances and minute Structure of Bone—Physical Properties and Chemical Composition—The Growth of Bone and its Mode of Development in Cartilage and Membrane.

BONE.

Microscopical Appearances and Structure.

If a transverse section of bone is examined under the microscope, it is seen to consist of a number of circular systems, each possessing a central aperture, arranged around which are little irregular spaces with small canals extending from them in all directions. The spaces (P. I. Fig. 1) are called *lacunæ* (P. I. Fig. 1, *b*), and lodge the bone-cells, and the channels leading out from them are called *canaliculi*, and lodge the processes of the bone-cells in the recent state. The canaliculi of the separate lacunæ communicate with one another, and also with the central aperture. If a longitudinal section of bone is now observed, it will be seen that the central apertures in the circular

systems are the cut ends of canals, which, running lengthways through the bone, communicate with each other by lateral branches, and are called *Haversian canals* (P. I. Fig. 1, *a*). They are about $\frac{1}{500}$th of an inch in diameter, and contain a small artery derived in some instances from the *periosteal* vessels, and in others from the vessels of the *endosteum.* The lacunæ and canaliculi absorbing nutrient material from them convey it to the ultimate parts of the bone. The Haversian canals are surrounded by a variable number of concentric lines, from five to ten, or more, called the *Haversian lamellæ*, and between these lamellæ are the lacunæ and canaliculi. The Haversian canal, together with the concentric lamellæ, and lacunæ, and canaliculi, constitute what is known as an *Haversian system.* Every lacuna is occupied by a nucleated mass of protoplasm, the *bone-cell* or *osteoblast* which sends its processes into the canaliculi and presides over the nutrition of the osseous substance. Beside the lamellæ mentioned above as being concentric with the Haversian canals, there are other lamellæ which are parallel with the

medullary canal and with the surface of the bone, and these have been named '*perimedullary*' and '*peripheric*' systems of lamellæ. There are a third set of lamellæ which do not coincide with either of these systems, but are placed between them ; these are called '*intermediary*' lamellæ, and are the remains of old Haversian systems which have been removed by gradual absorption. In the neighbourhood of these lamellæ are often seen vacuities or spaces, formed also by absorption of the tissue, and called *Haversian spaces.* (P. I. Fig. 1 d.) The lamellæ form the proper substance of the bone. If the earthy matter be removed by steeping the bone in acid it will be seen that the lamellæ present a definitely fibrous structure, the fibres are transparent and decussate with one another so as to form a finely reticular network. The external peripheric reticular lamellæ are in many places perforated by tapering fibres resembling in character white fibrous tissue, which bolt the lamellæ together, and may be drawn out when they are torn apart ; these are known by the name of the perforating fibres of Sharpey.

The texture of the bone varies considerably in different parts of the same bone as well as in different bones. In some parts the bone is dense or compact, while in others it possesses numerous spaces, and is open in structure, when it is said to be spongy or cancellated. In long bones the shaft is made up almost entirely of compact bone possessing only a thin layer of cancellar tissue on the interior; while the articular ends are composed almost entirely of cancellous tissue with only a thin layer of compact bone outside.

Occupying the centre of a bone is the medullary canal, originally formed by absorption from an Haversian canal; it is lined by a highly vascular areolar tissue called the *endosteum*, which is also prolonged into the smaller cavities in the cancellous tissue at the articular ends. The *marrow* of bones differs from ordinary fat tissue in the small amount of supporting areolar tissue it possesses, the cells being supported by spiculæ and lamellæ of bone, which project into the medullary canal. It is composed of about 96 parts of fat, the remaining 4 parts being made up of fluid and supporting tissue. Cells closely

resembling lymphoid corpuscles, but possessing no nucleus, and capable of performing amœboid movements have been seen in it. In the cavities of the cancellous tissue in the articular ends of long bones, and in other bones, as the sternum, ribs, and vertebræ, a reddish fluid, formerly supposed to be marrow, exists; but it differs from marrow in only containing a trace of fat. It contains about 75 per cent of water and 25 per cent of albumin, fibrin, and salts.

Vascular Supply.—The surfaces of bones, except the part covered by articular cartilage, are invested by a fibro-vascular membrane—the *periosteum*—which consists of an *outer* layer—which is composed of fibrous tissue, which serves for the attachment of tendons, and contains a quantity of blood-vessels—and an *inner* layer, which contains cells, and presides over the nutrition and growth of the bone. The nutrient artery, which enters at the nutrient foramen, makes its way to the medullary canal, and supplies the marrow and endosteum. A few of the endosteal vessels pass to the Haversian canals which are nearest the medullary canal; but by far the

greater number of the Haversian blood-vessels are derived from the periosteal vessels. A few vessels also enter the bone at the articular ends to supply the cancellous tissue. A long bone derives its vascular supply from three sources :—

i. From the nutrient artery which supplies the marrow and endosteum.

ii. From vessels which are derived from the periosteum, and, entering vascular foramina on the surface of the bone, find their way to the Haversian canals.

iii. From vessels which supply the cancellous tissue at the articular ends.

Nerves.—A few small nerves have been seen to enter the bone together with the nutrient artery, and reaching the medullary canal, they are distributed to the endosteum; some also accompany the vessels which enter at the articular ends of the bone (Kölliker).

Lymphatics have been seen to enter the bone substance, but their ultimate distribution within it has not yet been accurately determined.

Physical Properties.

Bone is tough and elastic, and possesses

great power of resisting pressure. It is of a pink and slightly bluish colour in the living state, but is white when dead. The specific gravity varies from 1·898 to 1·964. The elasticity of a bone is well shown in such bones as the ribs and clavicle.

Chemical Composition.

Bone is composed of both animal and mineral matter; the former constituting about 33 per cent and the latter 67 per cent of the whole. The animal matter, when it is boiled, yields gelatine. The mineral matter is composed of about 57 parts of calcium phosphate, 8 parts of calcium carbonate, 1 part of calcium fluoride, and 1 part of magnesium phosphate. The relative proportion of animal and mineral matter varies in different bones in the same individual, and in the same bone at different ages. The spongy flat bones contain from 12 to 30 per cent of water, and the compact tissue from 3 to 7 per cent. The earthy matter may be separated from the animal portion by burning the bone in an open fire: at first it becomes black, owing to the charring of animal matter, but subsequently

become white, brittle, and chalk-like. The animal part, on the other hand, can be separated from the mineral by steeping the bone in dilute hydrochloric acid—the lime salts are then dissolved out, and a tough but flexible substance remains, which retains the original shape of the bone. When the earthy part is thus removed the bone is found to have lost about two-thirds of its weight.

Development of Bone.

All bones may be divided according to their development into two classes.

i. Those ossified directly in membrane, as the bones forming the vault of the skull.

ii. Those which previous to ossification are laid down in cartilage, as, for instance, the humerus and femur. The intra-cartilaginous ossification, or development of bone from cartilage, is not to be regarded as in any sense a metamorphosis of cartilage into bone, but rather as a substitution of bone for cartilage, in which the following stages may be generally recognised.

i. The cartilage cells arrange themselves in rows parallel to the longitudinal axis of the bone.

ii. There is a deposition of lime salts between the cell; this is called 'the calcification of the matrix.'

iii. The absorption of the calcified matrix.

iv. *Pari passu* with the absorption of the calcified matrix there is an invasion by blood-vessels and osteogenic membrane, which is continuous with, and similar to the deep layer of the perichondrium. This bringing with it a quantity of cells, constitutes the cell proliferation stage.

v. The ossification of the intercellular portion of the new membrane.

vi. Most of the cells are left forming the bone corpuscles, the spaces in which they lie forming the lacunæ, while others form the *red* or *young* marrow cells.

vii. The formation, by absorption, of the medullary canal, and the production of yellow or adult marrow.

The process of intra-membranous ossification is similar to that in cartilage if we except the previous calcification. The membrane from which the bone is developed is similar to the perichondrium in structure. The deep layer of this membrane, bringing with it blood-

vessels and young cells, extends into the adjacent fibrous texture, and a deposit of calcareous matter takes place, forming a centre from which irregularly pointed processes radiate. The calcareous deposit extends till the whole of the intercellular membrane is ossified; spaces being left for the vessels and bone-cells, which constitute the *Haversian* canals and lacunæ, as in the intra-cartilaginous form of ossification.

Growth of Bone.

Calcareous deposits, which are called *centres* of ossification, take place in one or more points in all bones. Typical long bones have at least three such centres: one from which the shaft or *diaphysis* is developed, and the others for each articular extremity or *epiphysis*. The increase in length of a bone takes place almost entirely between the epiphysis and the shaft. If ivory pegs are driven into the shaft of a growing bone the distance between them does not increase appreciably, no matter how long they may remain there; but if one peg is placed in the shaft, and a second in the epiphysis of a growing bone, as the bone increases in length the distance between the

pegs becomes greater; showing, that growth in length takes place by the ossification of the cartilage between the epiphysis and the shaft. Increase in girth takes place by the deposition of new bone from the inner layer of the periosteum. This may be proved by the fact that a metal ring placed beneath the periosteum soon becomes covered by new bone; while if it be placed between the two layers of the periosteum, or superficial to them, no bony deposit takes place upon it. As new bone is being deposited on the outside absorption is taking place within: the two processes, indeed, going on concurrently. This mode of increase of a bone in length and thickness may be further illustrated by feeding an animal upon *madder*, when, as the earthy constituents of the newly formed bone unite with the colouring matter, it becomes deeply tinged, and the bone which is of new formation can be easily distinguished. The knowledge of the fact that a bone increases in length by the ossification of the cartilage between the epiphysis and the shaft is of practical surgical importance, for if the epiphysis, together with the intermediate carti-

lage, be removed from a bone, growth in length, at that extremity, cannot take place.

Uses.

Bones form the framework of the body, supporting the soft tissues, protecting important internal organs, as, for instance, the brain and spinal cord, and the thoracic and some of the abdominal viscera, and forming, in the limbs, a system of levers worked by muscles, by means of which the various movements of the body are affected.

CHAPTER V.

Anatomical Parts of a Tooth—Microscopical Appearances and Structure of *Dentine*—Enamel and *Crusta Petrosa*—The *Pulp* Cavity and its Contents—Development of Teeth—Permanent Dentition.

TOOTH.

Parts of a Tooth.

The teeth are firmly imbedded in sockets, or alveoli, in the upper and lower jaws. That part of a tooth which is placed above the line of the gum, and is exposed to wear, is called the *crown* or body; the constricted portion at the line of the gum is called the *neck;* while every tooth possesses one or more *fangs,* which are buried in a socket formed in part by the bone, and partly by the dense mucous membrane of the mouth which constitutes the *gum* (P. II. Fig. 6).

Occupying the interior of a tooth is a cavity, called the *pulp cavity* (P. II. Fig. 7). It contains the dental pulp, which is made up of loose areolar tissue, with blood-vessels and nerves, and some stellate or oval protoplasmic cells, closely resembling the bone-

cells, which line the margin of the pulp cavity and send their processes into the *dentine* tubules. These have been named tooth-cells or *odontoblasts.* Leading from the pulp cavity are small canals, which traverse the fangs and open at their points, and it is by means of these canals that the blood-vessels and nerves reach the dental pulp. The greater part of the body of a tooth is made up of a substance called *Dentine* (P. II. Fig. 7).

MICROSCOPICAL APPEARANCES AND STRUCTURE OF DENTINE.

When looked at under the microscope, dentine is seen to possess a solid but transparent matrix, which is crossed by numerous tubules, radiating from the pulp cavity towards the outer surface of the tooth, and communicating by their wider ends with the pulp cavity, while their outer extremities, which are much narrower, come in contact with the under surface of the enamel and cement. The tubules being filled with air look dark. They divide and subdivide dichotomously, and send off minute branches. When looked at in a mass they are seen to

pursue a wavy, undulating course, and to present two or three gentle bends or curves; these are called the *primary curvatures.* When, however, the dentine is examined with a higher power the individual tubules are seen to be twisted spirally upon themselves. These spiral twistings are called the *secondary curvatures* (P. III. Fig. 8). In the recent state the tubules contain the processes of the odontoblasts, which are prolonged into them from the cells as they line the margin of the pulp cavity. Fine nerve filaments have also been traced into the tubules with the cell processes. Near the outer surface of the dentine a modification of the matrix exists. It is broken up into spaces, globular in form, but varying much in size, and said to be due to an imperfect calcification of the matrix. Near the surface of the dentine there is often to be observed a layer, in which these spaces are very small and placed closely together; this is called the *granular layer* of Purkinje.

Properties and Composition.

Dentine or ivory is a hard, resistant material; it is somewhat harder than bone, con-

taining 72 per cent of mineral, and 28 per cent of animal, matter. The mineral matter is composed chiefly of phosphate and carbonate of *lime*, with traces of fluoride of calcium and phosphate of magnesia.

ENAMEL.

This covers the dentine, which forms the exposed portion of the tooth, and it gradually becomes thinner at the neck, where it ceases. (P. II. Fig. 7.)

Microscopical Appearances.

Enamel, which is developed from epithelium, is composed of solid hexagonal fibres of about $\frac{1}{5000}$th of an inch in diameter, which radiate from the dentine and fit into depressions on its surface. At the top of the tooth they are for the most part vertical, while towards the sides they are horizontal. The fibres, which are seen to be marked by transverse lines, are usually solid. Coating the outside of the enamel in unworn teeth is a very thin membrane; this is called the '*Cuticle* of the Enamel.'

Properties and Composition.

It is the hardest tissue in the body, containing only 3 per cent of animal, and about

97 per cent of mineral, matter. The mineral constituents are the same as those met with in dentine and bone.

CEMENT, OR CRUSTA PETROSA.

The Crusta Petrosa is bone modified in structure; it is met with below the line of the gum, investing that part of the dentine which is not covered by the enamel. Its lacunæ and canaliculi are larger and more irregular than those of ordinary bone, and it possesses no Haversian canals. In some instances the canaliculi which are nearest the dentine communicate with the termination of the dentine tubules.

Development of the Teeth.

The successive steps in the development of a tooth may be represented in the following order:—

1. Thickening of the epithelium covering the jaw, and formation of a groove in which the epithelium is contained. The groove is called the *Primitive Dental Groove*, and the epithelium lying in it the '*General Enamel Germ.*'

2. Secondary involutions of the general enamel germ, corresponding to the sockets

of the future teeth, take place. These are called the '*Special*' *Enamel Germs*.

3. The up-growth of a vascular papilla, which indents the epithelial process till it forms a cap for the dental papilla.

4. The pedicle or stalk of cells, by which the special enamel germ is connected with the free surface, gradually disappears, and the tooth becomes enveloped in its dental sac, which is formed by the growing together of the dental groove over and between the dental papillæ.

5. The papilla becomes moulded into the shape of the crown of the future tooth.

6. A cap of dentine is slowly deposited on the surface of the papilla, which increases in extent by additions to its edges, and in thickness by additions to its interior.

7. The substance of the papilla gradually decreases, and persists as the pulp of the future tooth.

8. The columnar epithelial cells of the enamel germ in contact with the dentine are calcified, forming the enamel, while the superficial layers remain, forming the cuticle of the enamel.

9. As the tooth grows upwards, the fang is

gradually calcified, and the cement is deposited on it from the inner layer of the dental sac.

10. Each tooth gradually developes, and pressing on the wall of the sac inclosing it, and causing its absorption, bursts through when it is said to be '*cut*.'

Development of the Dentine.

From the description given above, it will be seen that the dentine is developed from the cells on the surface of the dental papilla—growing, indeed, at the expense of the dental papilla—the papilla gradually diminishing as the dentine increases in amount. The cells of the pulp become elongated, and send out processes; the substance of the pulp between these processes undergoes a kind of calcification, so that the pulp gradually becomes transformed into the solid matrix of the dentine. The calcareous deposit takes place around the processes of the cells forming the channels in which they lie, which are indeed the *dentine tubules*.

The *cement* which, as stated above, closely resembles ordinary bone, is developed, in the same manner as the superficial layers of bone, from the deeper layer of the periosteum.

Permanent Dentition.

Some of the cells of the special enamel germ are, as it were, shut off from the rest in a little flask-like prolongation from the dental sac of each milk-tooth. This gradually enlarges, and a papilla becomes developed in its interior, from which a new tooth is formed. As the new tooth increases in size it presses upon the root of the corresponding milk-tooth, and causes its absorption, so that it finally falls out, or is *shed.* And in this way all the milk-teeth are in time replaced by teeth of the permanent dentition. At the time when the dental sacs are formed by the growing together of the dental groove, the portion of the groove posterior to the last temporary molar follicle remains unobliterated, and forms a cavity which is occupied by a prolongation backwards of the enamel germ; subsequently a papilla makes its appearance at the bottom of this cavity, and forms the rudiment of the first permanent molar tooth. The deeper portion of this gradually closes in around the papilla and forms its dental sac; but the more superficial portion, extending backwards, forms another cavity of reserve, in which the

second permanent molar tooth is developed; from this another prolongation backwards occurs, forming a cavity in which the wisdom tooth is developed. The subsequent development of the permanent molar teeth resembles in all respects that of the temporary teeth described above. The teeth of the lower jaw make their appearance somewhat earlier than those of the upper jaw; speaking generally, from the sixth to the seventh year the greatest number of teeth are to be met with in the jaws, as at that period there are all the milk-teeth, as well as all the permanent teeth present, with the exception of the wisdom teeth, and the rudiments of these may even be observed at this period. The following are the approximate dates of the eruption of the permanent teeth:—

Incisors (central)	appear about	7th year.
,, (lateral)	,,	8th ,,
Canines	,,	11th or 12th year.
Bicuspids (anterior)	,,	9th year.
,, (posterior)	,,	10th ,,
Molars (first)	,,	6th ,,
,, (second)	,,	12th or 13th year.
,, (third)	,,	17th to 25th ,,

CHAPTER VI.

ACTIVE TISSUES.

Structural Elements of Nerve Tissue—Varieties of Nerve Fibres, their Microscopical Appearances and Minute Structure—Nerve Cells—Structure of Ganglia—Central and Peripheral Terminations of Nerves—*Tactile Corpuscles*, *Pacinian Bodies*, *End Bulbs*—The Positions in which they occur—Properties and Composition of Nerves—Their Uses.

NERVE.

In describing nerve-tissue, two different structural elements have to be spoken of, namely, *nerve-fibres* and *nerve-cells*. Two kinds of nerve-fibres are distinguished, first, the *white*, *medullated*, or *dark-bordered*, and secondly, the *grey*, *pale*, or *non-medullated*.

The white or medullated nerve-fibres are met with chiefly in the cerebro-spinal nervous system, but they also occur sparingly in the sympathetic system. The grey or non-medullated nerve-fibres, on the other hand, are the characteristic fibres of the sympathetic nervous system. When a perfectly fresh medullated nerve-fibre is examined under

the microscope, it apparently consists of a transparent oil-like material contained within a limiting membrane; when examined some time after death, or after the action of various reagents, more definite structural characters can be made out. After exposure to air or water for a short time, a kind of coagulation occurs, and the oil-like material immediately within the limiting membrane becomes opaque and granular; when this takes place, the outline of the tube, which was previously transparent, acquires a dark, double contour, the outer line being formed by the limiting membrane, and the inner by the coagulated oil-like material. While these changes are taking place, a greyish band or streak, occupying the centre of the tube, makes its appearance. It now becomes apparent that each nerve-fibre consists of three distinct parts (Pl. III. Fig. 10).

1. Of a delicate membrane, composed of fine elastic fibres covered superficially by a layer of flattened nucleated cells, and called *the primitive sheath of Schwann.*

2. Contained within this membrane is a granular material which resembles fat in

being highly refractive, and in being readily dissolved by ether, and stained black by osmic acid. This is called *the white substance of Schwann* or *Medulla*.

3. Occupying the centre of the tube is an albuminous material forming a greyish streak or band, called the *axis cylinder*.

The primitive sheath serves as an investing membrane to the nerve-fibre, and is purely protective in its nature. In some special positions, to be noticed further on, it is absent.

The white substance of Schwann acts as an insulator, and prevents the radiation of the nerve-current to adjacent nerve-fibres. It is a fatty and albuminous material, and is rendered opaque and brown by the action of chromic acid; the ease with which it is dissolved by ether, and stained black by osmic acid, fully indicates its fatty nature.

The axis cylinder is the essential part of the nerve, and the conductor of nerve force. This assumption is based on the fact that the axis cylinder is always present, whatever other constituent of the nerve-fibre may be

absent, and its continuity is never interrupted. The axis cylinder has sometimes been observed to split up into delicate longitudinal fibrillæ. This is well shown in the cornea, where the axis cylinders of the nerve-fibres break up into numerous fibrillæ, which go to form terminal networks, and also in the spinal cord, where these fibrillæ form a large portion of the grey matter.

Unlike the white substance, it is unaffected by chromic acid, but it is stained red by an ammoniacal solution of carmine, a reagent which has no effect on the white substance. Ranvier described the occurrence of annular constrictions or breaks in the continuity of the white substance, which may be observed in all medullated nerve-fibres at intervals of about $\frac{1}{25}$th of an inch. These breaks are called the *nodes* of Ranvier. They may be readily brought into view by the action of osmic acid, which stains the white substance black, but leaves the nodes almost colourless (Pl. III. Fig. 9). In each interannular segment between the white substance and the primitive sheath, a clear oval nucleus may be seen, with a certain amount of granular proto-

plasmic material around it; where the breaks occur, the primitive sheath dips down and surrounds the axis cylinder. Placed between the segments, there is a certain amount of semi-gelatinous material, called the *intersegmental substance* of Ranvier. The nodes of Ranvier are absent from the non-medullated nerve-fibres.

In some cases, the white substance of Schwann is irregularly disposed, being swollen out at certain parts and irregularly contracted at others. The nerves where this arrangement of the white substance occurs are called *varicose* nerve-fibres, and they are usually destitute of a primitive sheath. These fibres are met with in the optic, auditory, and olfactory nerves, and they occur also in the brain and spinal cord.

NON-MEDULLATED NERVE-FIBRES.

Grey nerve-fibres frequently possess an investing sheath, which corresponds to the primitive sheath in the medullated variety; in this sheath nuclei are often visible. Within the sheath is an axis cylinder, which possesses the same characteristics as that of the white nerve-fibres, being composed of extremely

delicate fibrillæ, with a certain amount of granular material between them.

Microscopical Appearances.

When examined under the microscope, grey nerve-tissue is seen to consist of fibres which possess a straight but indistinct outline, and generally having a yellowish-grey hue (Pl. III. Fig. 12). Microscopically they differ from the white variety, in that they possess no double contour, no dark refracting outline, no nodes of Ranvier, no granular appearance, no varicosities, and they are much smaller in size than the medullated fibres, and of a greyish colour.

Varieties of Nerve-fibres.

Nerve-fibres exist in very varied forms. In some, the primitive sheath and white substance may be absent; in others, one or other of these may be absent, but the axis cylinder is always present. We may have nerves made up of one fibrilla, and possessing a greater or less amount of medulla, or we may have them made up of a bundle of fibrillæ without any medulla or sheath. The various modifications of nerve-fibres have been enumerated under six heads:—

1. Primitive fibril without sheath or medulla.

2. A bundle of primitive fibrils without sheath or medulla.

3. A bundle of primitive fibrils with a sheath.

4. A primitive fibril with medulla.

5. A bundle of primitive fibrils with medulla.

6. A bundle of primitive fibrils with medulla and sheath.

The above is a description of the structure of individual nerve-fibres; let us now see the way in which *nerve-fibres* are associated together to form *a nerve*. In the first place, a number of nerve-fibres are enclosed in a tubular sheath, forming a slender cord called a *funiculus*; several of these funiculi are then bound together by a common sheath of fibro-areolar tissue to form a nerve. The tubular membrane which binds the nerve-fibres together to form a funiculus, is made up of two or three lamellæ of delicate reticular tissue, with flattened epithelioid cells on the surface, and is called the *neurilemma*. The denser sheath which binds the funiculi to-

gether to make a nerve, and invests the whole nerve, is made up of areolar tissue, sometimes so dense that it might well be called fibrous tissue, has received the name of the *cellular sheath.* The following, then, is the arrangement of the investing sheaths met with in a nerve :—the primitive sheath invests the nerve-fibre; the neurilemma invests the funiculus; while the cellular sheath invests the whole nerve. Blood-vessels and lymphatics exist in the nervous cords.

NERVE-CELLS.

Nerve-cells are met with in the grey matter of the spinal cord and brain; and from the fact that they form an important part of the nervous ganglia, are often called *ganglion cells.* They constitute the second structural element in the nervous system. Besides existing in the cerebro-spinal centre, nerve-cells are in some cases met with in the peripheral expansions of the nerves of special sense, and in some cases, also, in the course of other nerves. Nerve-cells vary much in their size and form as well as in their structure; the simpler varieties are round or oval, while the larger are polygonal and

stellate. In many cases, nerve-cells, especially those met with in the spinal cord and brain, send out processes which are often finely branched, and such cells are called, according to the number of processes they have, unipolar, bipolar, or multipolar cells (Pl. III. Fig. 13).

Nerve-cells usually possess a well-marked nucleus, and contain one, and often two nucleoli. The interior of the cells is made up of a soft, somewhat granular substance, which is frequently fibrillated; in the neighbourhood of the nucleus, they are often stained a darker colour by groups of brown or yellow pigment granules. In some cases a distinct cell-wall can be plainly seen, while at other times it is not so plainly visible. In the brain and spinal cord, the nerve-cells are imbedded in a very fine reticular tissue—the neuroglia, while in the smaller nerve ganglia, as in the sympathetic ganglia and the ganglia on the posterior roots of the spinal nerves, the nerve-cells are surrounded by a distinct fibrous tissue capsule. Kölliker has differentiated this capsule into two distinct layers, namely, an outer fibrous layer and an inner

layer, composed of a simple layer of flattened endothelial cells.

The processes of the cells are prolongations of the granular material which composes its substance. Some of these processes, after dividing and subdividing minutely, terminate at a variable distance from the capsule; others, again, intercommunicate freely with the processes of other cells, while some are continuous with the axis cylinder of a nerve-fibre, gradually acquiring a white substance and primitive sheath. This last-named mode of connexion of nerve-cells with nerve-fibres, may readily be traced out in the anterior cornua of the grey matter of the spinal cord. As stated above, nerve-cells, though in many cases existing separately, as in the cerebro-spinal centre, are at other times associated together to form nerve-ganglia. The substance of these ganglia is made up of these cells, together with an intercellular supporting fibrous stroma, and they are surrounded externally by a capsule, derived from the external sheath of the nerve, which sends processes into their interior. The individual cells within the ganglion are surrounded by a delicate nucleated capsule, which is probably

continuous with the primitive sheaths of the nerves which enter the ganglion (Pl. IV. Fig. 16). When a nerve enters a ganglion, it splits up into its constituent fibres, which pass between the nerve-cells occupying the interior of the ganglion; but on quitting it, these fibres are again associated together to form distinct nervous cords, surrounded by the usual investing sheaths. Every nerve-cell is connected with one or more nerve-fibres, but many nerve-fibres have been observed to pass through a ganglion without being connected with a nerve-cell.

NERVE TERMINATIONS.

The terminations of nerves may be divided into central and peripheral. The way in which nerves are connected centrally in the brain and spinal cord has not yet been clearly made out; but the following are some of the chief modes of connexion of nerve-fibres with nerve-cells which have hitherto been described :—

1. Some specially modified nerve-cells have been described by Beale, as existing in the ganglia of the sympathetic system of the frog. The cells are pear-shaped, and from their narrow extremity two nerve-fibres arise; one of these fibres is straight, and the other spiral.

The straight fibre passes into the interior of the cell substance, and forms, as it were, the stalk of the cell. The spiral fibre apparently begins nearer the periphery of the cell, and making several turns around the cell, within its capsule, is continued in spiral coils around the straight nerve-fibre. On arriving at the nervous bundle to which they are distributed the fibres turn in opposite directions (P. IV. Fig. 14). Both fibres are distinctly nucleated, and at first only present the characters of an axis cylinder; but they subsequently acquire a medullary and primitive sheath.

2. Two methods of connexion of nerve-fibres with cells have been described by Gerlach. In the first instance, from the many processes of a nerve-cell, one, which is unbranched, and which springs either directly from the body of the cell, or from its chief and broadest process, has been seen to become invested at a variable distance from the nerve-cell by medulla, subsequently acquiring a primitive sheath, thus forming a nerve-fibre, the axis cylinder of which is formed by the unbranched process of a nerve-cell (P. IV. Fig. 15). In the *second* case a

nerve-fibre has been seen to divide, and the two branches which result from its division to communicate with the delicate fibrils formed by the subdivision of the processes of two nerve-cells (P. IV. Fig. 17).

3. Lastly, the axis cylinder of a nerve-fibre, has been seen to become continuous with the fine fibril resulting from the union of the finely divided processes of two or three nerve-cells ; but this communication takes place by the intervention of a bipolar cell, one pole of which is continuous with the fine fibril derived from the processes of the nerve-cells, and the other with the axis cylinder of the nerve-fibre.

PERIPHERAL TERMINATIONS OF NERVES.

The way in which nerves terminate peripherally may be represented as follows :—

A. *Motor nerves terminate,—*

1. In striated muscle—in motor end plates.

2. In unstriated muscle—in plexuses.

B. *Sensory nerves terminate,—*

1. In the skin, in plexuses and different endings, as,—

(*α*) Tactile corpuscles.
(β) Pacinian bodies.
(γ) End bulbs.

2. In mucous and serous membranes ;—
   (i.) In plexuses.
   (ii.) In end bulbs, also, in the mucous membranes.

3. In the organs of special sense in different endings ;—
   (*a*) In the eye ;—
      (i.) In cells, in the rods and cones of the retina, and in the cornea.
      (ii.) In free ends in the cornea.
   (*b*) In the ear ;—
      (i.) In cells connected with the organ of Corti in the cochlea.
      (ii.) In free ends in the vestibule and semicircular canals.
   (*c*) In the nose, in the cells, and in free ends.
   (*d*) In the tongue, also in cells and free ends.

NERVE ENDINGS IN MUSCLE.

1. *In striated muscle.*

A nerve on passing to be distributed to a muscle breaks up within the muscle into its constituent fibres, which form plexuses, which become finer the more deeply they penetrate the substance of the muscle. Ultimately an

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individual nerve-fibre ends in a single muscle fibre. The primitive sheath of the nerve-fibre becomes continuous with the sarcolemma of the muscle fibre, the white substance of Schwann stops short, while the axis cylinder, piercing the sarcolemma, becomes spread out beneath it, forming a flattened expansion, around which is an aggregation of granular protoplasmic material, with large bright nuclei imbedded in it. Where the nerve-fibre thus ends in the muscle fibre a slight elevation is produced on the side of the muscle fibre, which is called the *nerve eminence* (P. VI. Fig. 22).

Beale, and others maintain that the ultimate ramifications of the nerve-fibres do not pierce the sarcolemma; but they state that the nerve-fibres form extremely delicate nucleated plexuses, which ramify on, and around the muscle fibres. Krause, again, while describing the nerves as terminating in an end plate, regards the plate as being placed external to the sarcolemma.

2. *In unstriated muscle.*

The nerves which are distributed to unstriated muscle are chiefly non-medullated.

They form, in the first instance, coarse plexuses between the bundles of fibres, and from these more minute fibrils are prolonged, to form still more delicate intra-muscular plexuses between the individual cells. The terminal filaments of these plexuses have been traced into the nuclei of the muscle fibre cells.

SENSORY NERVES.

Special endings—end bulbs, tactile corpuscles, and Pacinian bodies; resemble one another in that they each possess a capsule of delicate areolar tissue, within which is a core of soft, translucent material. They agree also in the fact that one or, in some cases, more nerve-fibres pass into the interior of each of them, and end in the core in a knobbed or twisted extremity. The Pacinian bodies, beside possessing a delicate areolar capsule, have, in addition, an inner capsule, composed of a lamellar structure, which will be described more fully in speaking of those organs.

END BULBS (P. VI. Fig. 25).

These bodies, as stated above, possess a delicate areolar tissue investment, which forms a distinct capsule. In the capsule are seen nuclei, oval in shape, which are placed

vertical to the axis of the end bulb. Occupying the centre of the organ is a core, composed of soft, translucent material, in which small granules, which have the appearance of minute particles of fat, make their appearance when it is exposed to the action of a solution of soda. On reaching the end bulb the *primitive sheath* of the nerve fibre passes into, and becomes continuous with, the capsule of the body, the *white substance* of Schwann gradually disappears, while the *axis cylinder*, entering the core, becomes twisted on itself, and ends at the near end of the core in a knobbed extremity.

Where found.

1. On the sclerotic conjunctiva.

2. In the lips, tongue, and soft palate, where they are placed in papillæ.

3. On the glans penis.

End bulbs are generally spherical in shape, and are about $\frac{1}{800}$th of an inch in diameter.

TACTILE CORPUSCLES (P. VI. Fig. 23).

These bodies possess a capsule and central core, which resemble in almost every particular those of the end bulbs. The nuclei in the capsule of the tactile corpuscles are arranged

transversely to the axis of the corpuscle. The nerve-fibre on arriving at the corpuscle winds spirally round it till it reaches the summit, where the *primitive sheath* becomes continuous with the capsule, the *white substance* gradually ends, and the *axis cylinder* piercing the capsule ends in the top of the core. Tactile corpuscles are rather more oval in shape than the end bulbs, and are about $\frac{1}{300}$th of an inch in length and thickness.

Where found.

1. In the palms of the hands and soles of the feet, and to a less extent on their dorsal surface.

2. On the nipple.

3. On the glans penis.

The papillæ in which they are situate are usually devoid of blood-vessels, hence they are named *tactile* papillæ, so as to distinguish them from the ordinary papillæ of the skin, or, as they are termed, the *vascular papillæ.*

PACINIAN BODIES (P. VI. Fig. 26).

Pacinian bodies differ from the two terminal organs just described, in that they possess in

addition to the external capsule and the central core. an inner capsule, which is composed of several lamellæ, which encase one another like the coats of an onion. These lamellæ surround the central core, and are composed of very fine elastic fibres, lined on their inner surface with a layer of flattened nucleated cells. Between the lamellæ there is a certain amount of clear pellucid fluid. Pacinian bodies possess a stalk or peduncle, by means of which they are attached to the nerve-fibre with which they are connected, and in this respect they differ from both the end-bulbs and tactile corpuscles. They are generally oval in shape, and are about $\frac{1}{15}$th to $\frac{1}{20}$th of an inch in length.

When the nerve-fibre reaches the Pacinian body; the primitive sheath becomes continuous with the lamellæ of the inner capsule, the white substance ends in the peduncle, and the axis-cylinder passes to the far end of the core where it ends in a twisted extremity.

Where found.

1. In the mesentery, especially that of the cat.

2. Attached to the branches of nerves in the hand and foot (P. VI. Fig. 24).

3. On the nerves which are distributed to joints.

4. On the periosteal nerves.

5. On the intercostal nerves.

6. On the pudic nerves, in the glans penis, and in the bulb of the urethra.

7. On many of the cutaneous nerves of the upper extremity and neck, and on the infra-orbital nerve.

THE SYMPATHETIC SYSTEM.

The sympathetic system of nerves consists of:—

1. Two gangliated trunks placed on each side of the spinal column.

2. Communicating branches which connect the sympathetic system with most of the cranial and all the spinal nerves.

3. Branches of distribution, which consist of (*a*) branches directly distributed in small plexuses; and (*b*) large plexuses with numerous ganglia.

The two gangliated trunks extend from the base of the skull to the coccyx, resting on the transverse processes of the vertebræ in the

neck, on the heads of the ribs in the dorsal region, and on the sides of the bodies of the vertebræ in the abdominal region, and ultimately unite at the coccyx to form the *ganglion impar.* The trunk of the sympathetic consists of a series of ganglia united by intervening nerve-fibres. In the sacral, lumbar, and dorsal region, the ganglia correspond to the number of vertebræ in each region; but in the cervical region there are only three, these representing the fusion of several smaller ganglia. As regards the communicating branches, it may be stated that those which connect the sympathetic ganglia with the anterior divisions of the spinal nerves, consist of a non-medullated fibre passing from the sympathetic to the spinal nerves, and of a medullated fibre which passes from the spinal nerves to the sympathetic. The branches of distribution, as stated above, consist, in the first instance, of primary branches, which pass off from the ganglionic chain or trunk of the nerve, and are distributed in the form of small plexuses on the adjacent blood-vessels, glands, and other organs. In the second case the branches of the sympathetic

are associated together to form large plexuses containing collections of nerve-cells. Three such plexuses exist: namely, the *pre-vertebral cardiac plexus*, placed at the base of the heart. The *pre-vertebral solar*, or epigastric plexus, placed around the cœliac axis. The *pre-vertebral hypogastric* plexus placed in front of the last lumbar vertebra. From these large plexuses branches are distributed to the thoracic, abdominal, and pelvic viscera. The nerves of the sympathetic system consist almost exclusively of the grey or non-medullated variety.

Properties and Composition of Nerves.

Nerve tissue contains a considerable quantity of water, varying from 70 per cent in the white to as much as 85 per cent in the grey substance.

The chemical composition of the brain may be stated as follows:—

IN 100 PARTS.

Water	80
Fats	5
Albumins	7
Extractives and salts	8

The albuminous substances are chiefly derived from the axis cylinder and the protoplasm of the cells, and they appear to be formed of a substance which is supposed to resemble fibrin and myosin ; it is, however, not soluble in dilute acids, or in a solution of potassium nitrate. The albumin of the medullary substance is soluble in dilute acids, and resembles casein. The salts, which form about 2 per cent, are composed chiefly of phosphates. The chief extractives are elastin, kreatin, leucin, xanthin, hypo-xanthin, lactic, and uric acids. Nerves, when in a state of rest, present a neutral or faintly alkaline reaction, but they become acid after death or on long-continued irritation.

Uses of Nerve Tissue.

Nerve-fibres are capable of conducting impulses from the point to which a stimulus has been applied either towards the centre or to the periphery. Those which conduct towards the periphery are called *motor* or *efferent*, and those which conduct towards the centre are called *sensory* or *afferent* nerves. Most of the spinal nerves are mixed nerves : that is, they consist of both motor and sensory fibres, and

these, though associated together in the same nerve, are separate at their origin. Each spinal nerve arises by two roots—an anterior, which is motor; and a posterior, which is sensory, and has a ganglion on it. In man, a sensory nerve impulse has been calculated to travel at the rate of about 140 feet a second.

Nerve-cells are either automatic, originating the stimuli which are conveyed to the efferent nerves; or they are reflex centres, receiving a stimulus from a sensory nerve and transferring it to a motor; or to another sensory nerve. When an impulse passes through a nerve-cell a considerable augmentation of energy takes place.

CHAPTER VII.

Classification of Muscle—Parts of a Muscle—Microscopical appearances and structure of Muscle, Fibres, and Fibrillæ—Connexion of Fibres with their Tendons—Vascular Supply—Nerves and Lymphatics of Muscles—Structure of unstriated Muscle and of the muscular Fibre of the Heart—Physical properties and chemical Composition of Muscle—The uses of muscular Tissue.

MUSCLE.

CLASSIFICATION OF MUSCLE.—In speaking of muscle tissue we may classify it either histologically, and divide it into the striated, and *unstriated*, or physiologically, when it may be divided into the quick-contracting, and slow-contracting—the quick-contracting being represented by the striated, and the slow-contracting by the unstriated variety. Muscle is frequently classed under the heads *voluntary* and *involuntary*, the striated variety representing the voluntary and the unstriated the involuntary; but this classification is misleading, as we have the notable instance of the muscle of the heart, which is striated but involuntary, and the equally important ex-

ception of the ciliary muscle of the eye, which is unstriated but voluntary in its action. In birds the ciliary muscle is of the striated variety.

STRUCTURE OF MUSCLE.—The fibres of striated muscles are aggregated together to form distinct masses or muscles, which vary much in size and shape. They terminate at each end in a tendon,—either abruptly or by a process of gradual continuity,—by which they are attached to the bones. The muscular fibres, which are made up of minute fibrils, are collected into bundles called fasciculi. The fibrils run parallel with one another in the fibres, and the fibres are parallel in the fasciculi. The fasciculi also are, as a rule, parallel with one another, although some converge towards the terminal tendon; but in the ordinary skeletal muscles they do not anastomose. Every muscle is invested externally by a continuous sheath of more or less dense areolar tissue, which sends in processes between the fasciculi or bundles of fibres, by means of which they are associated together to form the muscle (P. V. Fig. 18). Finer prolongations of the sheath, entering

the fasciculi, pass between the individual fibres, but they do not completely surround them. Besides connecting the fibres and fasciculi together, the prolongations of the sheath afford support to the nerves and vessels which ramify in the muscle substance.

MICROSCOPICAL APPEARANCES AND STRUCTURE OF THE FIBRES.—When a specimen of skeletal muscle is examined under the microscope the fibres are seen to be of a yellowish red colour, and possess well-marked transverse striations and less well-marked longitudinal ones (P. V. Fig. 21). Each fibre is invested by a yellowish membrane called the *sarcolemma*, which possesses the physical and chemical properties of yellow elastic tissue, and is sufficiently tough to allow of the included muscle substance being ruptured without being itself injured. Situate on the surface of the muscle fibre, but placed beneath the sarcolemma, are some clear oval nuclei, around each of which is a certain amount of granular protoplasmic material. These play an important part in taking up nutrient material from the adjacent blood-vessels, and preside over the growth and nu-

trition of the muscle. Kölliker has set down the diameter of muscle fibres as varying from $\frac{1}{750}$th to $\frac{1}{400}$th of an inch. The fibres rarely exceed one inch and a half in length. The fact that in examining striated muscle fibres under the microscope, longitudinal as well as transverse striations were observed, tells us that each fibre is again split up into fibrillæ, a bundle of fibrillæ surrounded by the sarcolemma constituting a muscle fibre.

STRUCTURE OF MUSCLE FIBRILS.—The study of the structure of the ultimate muscle fibrils is surrounded with great difficulty, and their exact structure has not yet been accurately determined. When examined under a high power, they appear to be made up of a number of dark quadrangular particles with a light intervening substance—these constitute the *sarcous elements* of Bowman. The two kinds of particles possess different refractive powers; the dark particles, according to Brücke, being doubly refractive, while the light substance only refracts light singly. According to Engelmann the fibres of muscle when fresh are transparent; and the appearance of superimposed disks are due to a kind

of coagulation which takes place, the advent of which is hastened by the addition of any reagent. The alternate arrangement of the dark and light particles gives the muscle its transversely striated appearance. The light particles in each fibre are crossed by little septa, described by Krause and called *Krause's membranes.* As these septa cross adjacent fibrils at the same level they run across the whole fibre, and appear to be firmly attached to the under surface of the sarcolemma. On either side of each membrane is a thin layer of light single refractile substance, to which the name *lateral disk* has been given. In the lateral disks, on either side of Krause's membrane, is a row of dark granules. Hensen has described a light band as crossing the dark particles, this has been termed the middle disk of Hensen; its precise nature has not yet been clearly made out. Schäfer takes another view of the structure of muscle; he describes a muscle fibre as being composed of a number of rod-like particles, which he calls muscle rods, placed side by side in the long axis of the muscle, with a certain amount of cement or

ground-substance between them. The rods traverse the dark particles, and terminate in knobbed extremities in the light substance; and the row of dark granules, described as being seen in the light substance on either side of Krause's membrane, are formed by the knobbed extremities of these rods. If a muscle fibre be treated with diluted hydrochloric acid for some time, it will be seen to split transversely into disks; this is due to the fact that the dark particles are less easily acted on by hydrochloric acid than the light ones, so that they can be separated from them by this reagent. So a muscle fibre can be separated not only longitudinally into fibrillæ, but also transversely into disks.

Connexion of Fibres with Tendons.—There has been considerable difficulty in determining the exact mode of connexion of muscle fibres with their tendons; but there seems to be little reason to doubt that they are connected with their tendons in one of two ways—either by *direct* continuity, the fibres of the muscle gradually passing into, and becoming continuous with the fibrous tissue of the tendon; or *indirectly*, by the

bundles of muscle fibre fitting into depressions in the tendon, the investing sheath of the muscle gradually becoming continuous with the fibrous tissue of the tendon. This last mode of termination is usually observed in those muscles—as the Gastrocnemius for instance—in which the fibres end obliquely in the tendon.

Vascular Supply.—Muscles are, as a rule, well supplied with blood. When an artery goes to a muscle it breaks up into branches, which grow finer, and are more closely placed together the more deeply they pass into the substance of the muscle. As they ramify around the fasciculi and between the fibres, they are supported by the processes of the investing sheath mentioned above. The branches of the vessels having undergone exceedingly minute subdivision, ultimately form fine longitudinal meshed capillary networks, which surround the individual muscle fibres; but no vessels pierce the sarcolemma to ramify in the substance of the muscle, the muscle substance proper deriving its nutrition from the adjacent vascular plexuses by a process of imbibition, in

which the oval nuclei, previously described, are, in all probability, actively engaged. *Lymphatics* exist in considerable quantity in the tendons and sheaths of muscles, and also in the fibrous septa which pervade the muscle substance. *Nerves* are to be met with in all the skeletal muscles, and their mode of termination within them has already been described in the chapter on nerve tissue when speaking of the peripheral terminations of nerves.

UNSTRIATED MUSCLE (P. V. Fig. 20).—Unstriated or plain muscle, as it is sometimes termed, is made up of bundles of fibres or fasciculi, the size of which varies in different localities. When the bundles of fibres have been teased out with needles, or exposed for a time to the action of dilute acid, they can be readily separated into elongated cells, called by Kölliker *contractile fibre cells.* They are thick in the middle and taper towards either end; they possess a well-marked nucleus; and in the interior of the cell a granular material is observed in the neighbourhood of the nucleus, which extends towards the ends of the cells. Very frequently faint longitudinal striations traverse the sub-

stance of the cells. The size of the cells varies considerably; their breadth is about $\frac{1}{4000}$ of an inch and their length from $\frac{1}{800}$ to $\frac{1}{300}$ of an inch. They possess no sarcolemma. Besides being associated together to form fibres and fasciculi, they are often met with either singly or united with a variable amount of other tissues. Unstriated muscles are generally supplied by the sympathetic system of nerves.

Where Found.

1. In the lower half of the gullet, in the stomach, and the whole of the intestinal canal.

2. In the middle coat of arteries, and the middle coats of many of the larger veins and lymphatics.

3. In the bladder and ureters, and in the ducts of the larger glands generally.

4. In the uterus and its appendages.

5. In the gall-bladder.

6. In the Corpora Cavernosa of both sexes and in the prostate gland.

7. In the dartos tunic of the scrotum.

8. In the trachea and bronchial tubes.

9. In the muscles attached to the hair follicles.

10. In the ciliary muscle and iris.

11. Throughout the skin generally.

MUSCULAR TISSUE OF THE HEART.

The heart muscle seems to occupy an intermediate place between the striated and unstriated muscular tissue. The fibres possess transverse striæ, which are not so well marked and less regular than those seen in ordinary skeletal muscles. The diameter of the fibres is also less. The fibres possess no sarcolemma, and they appear to be made up of irregularly quadrilateral cells, which are frequently forked at one extremity, and often, also, send out lateral offsets. Occupying the centre of the cell is a well-marked nucleus, and the substance of the cell, in some cases, presents a faint longitudinal striation. The muscular fibres of the heart freely divide and anastomose, the lateral prolongations of the cells causing them to adhere firmly together.

Composition of Muscle.

Muscular tissue contains between 70 and 80 per cent of water. If a piece of muscle be frozen and then reduced to a pulp, mixed with a salt solution, and cast on a filter, a weakly alkaline or neutral fluid is obtained,

which is called the *muscle plasma.* This fluid soon undergoes coagulation and separates into a solid portion, called *myosin,* and a fluid serum. Myosin is an albuminous body soluble in salt solution. The addition of weak acids readily dissolves it, but in doing so converts it into syntonin or acid albumen. Muscle serum, which at ordinary temperatures quickly acquires an acid reaction, contains a quantity of albumen, of which Kühne describes two varieties, the one coagulating at a temperature of 45° C, and the other, which is more abundant, which coagulates at 75° C. The serum also holds in solution certain extractives as kreatin, xanthin, uric acid, sugar, glycogen, inosite, an unfermentable sugar from the tissue of the heart, salts, and colouring matter. The following table of the composition of muscle, after Kühne, is taken from Ralfe's *Physiological Chemistry* :—

Water	74·0	... 80·
Solids	26·0	... 20·
Albuminous substances insoluble in water, as myosin, sarcolemma, nuclei, &c. ...	15·4	... 17·7
Alkali albuminate	2·2	... 3·0

Gelatine	0·6 ...	1·9
Kreatin	0·07 ...	0·14
Fat	1·5 ...	2·30
Lactic acid	1·5 ...	2·30
Phosphoric acid	0·66 ...	0·70
Potash	0·50 ...	0·54
Soda	0·07 ...	0·09
Sodium chloride	0·04 ...	0·09
Lime	0·02 ...	0·03
Magnesia	0·04 ...	0·05

The reaction of muscle when at rest is neutral, or faintly alkaline, but it becomes acid when it passes into a state of activity, and also during rigor mortis.

Uses of Muscular Tissue.

Muscular tissue is that by means of which the various active movements of the body are produced. Its fibres possess the power of contracting, or shortening, under the influence of certain stimuli, which are capable of calling into play the property of contractility they possess. This property of muscle, to shorten or contract, is made use of in the most varied manner ; and it is by means of the associated action of various groups of muscles that we are able to accomplish, not only such obvious, though highly complex, muscular actions as locomotion, respiration, and expression, but

also the more delicate and subtle ones, as those, for instance, by means of which we are able to perform the complex movements of the eyeballs, or to produce the various modifications of voice and speech.

CHAPTER VIII.

General characteristics of Epithelium—The several varieties of Epithelium and their Histology; the positions in which they occur—Uses of the Epithelia.

EPITHELIUM.

General Characteristics.

Epithelium is met with covering the surface of the skin and mucous membranes, and lining the ducts of glands as well as their terminal alveoli. In some cases it exists in many layers, and in others in only a single layer. It consists of cells, which vary much in shape and size, and are connected with one another by a kind of cement or ground substance, which is very slight in amount. The cells usually possess a well-marked nucleus, which is very large in comparison with the size of the cell, and one or more nucleoli. Epithelium is devoid of blood-vessels, and depends for its nutrition upon the vessels of the membrane on which it is placed. When the cells are arranged in

several layers the epithelium is said to be *stratified.* In such cases the deeper cells, which are placed nearest the vascular membrane, are generally oval in shape, and they differ physically and chemically, as well as in form, from those of the superficial layers: for the deeper cells are soft and readily affected by weak acids, the superficial cells being hard and horny in many cases, and not readily affected by these reagents. The intermediate layers of cells are irregularly spherical in shape, and, in fact, present a transitional form between the deep oval cells and the superficial scaly ones; the name *transitional* epithelium is sometimes given to these intermediate forms of epithelial cells. Thus in the stratified epithelia the cells undergoing considerable modifications gradually come to the surface, where they are cast off by desquamation. Fine nerve plexuses have been seen between the epithelial cells both in the skin and in the cornea. In some cases the terminal filaments of the nerves have been traced into the epithelial cells themselves. This continuity of the nerves with the epithelial cells has been

observed in the cells occupying the alveoli of some of the secreting glands, and in the cells of the rete mucosum in the skin.

Varieties of Epithelium.

The cells of epithelium are variously modified according to the situations in which they are placed, and the functions they have to perform.

Four chief varieties of epithelium are distinguished, namely :—

1. Squamous, scaly, tesselated, or pavement epithelium.

2. Columnar epithelium.

3. Spheroidal or glandular ;

4. Ciliated epithelium.

1. SQUAMOUS EPITHELIUM (P. VII. Fig. 27).

The cells of squamous epithelium are flattened into plates or scales. They generally possess a well-marked nucleus, which is large in comparison with the size of the cell, and the nucleus contains one, sometimes two nucleoli. The interior of the cells contains a number of faintly marked granules irregularly scattered about. The outline of the cells is exceedingly irregular, and they vary from $\frac{1}{1000}$th to $\frac{1}{500}$th of an inch in diameter.

Where Found.

Arranged in several layers it is found :—

1. Forming the epidermis.

2. Lining the mouth, pharynx, and œsophagus, the conjunctiva, the vagina, and the orifices of the urethra and anus.

3. As a single layer it is met with in the pulmonary vesicles, in the Malpighian capsules of the kidney, and in the rete testis.

4. Lining the interior of the heart, blood-vessels, and lymphatics, and also the serous and synovial sacs, is a single layer of flattened cells, the outline of which can be readily rendered apparent by treating them with nitrate of silver. The name given to this form of epithelium is *endothelium* (P. VII. Fig. 30). It differs from epithelium in being developed from the *mesoblastic* layer of the embryo, and in the fact that it always exists as a single layer.

2. COLUMNAR EPITHELIUM (P. VII. Fig. 28).

This variety of epithelium consists of cylindrical cells, which possess a large oval nucleus ; they are about $\frac{1}{500}$th of an inch in length, and are set upright on the surface

they cover. The nuclei of the cells are very distinct, and the interior of the cells is faintly granulated. The broad end of the cells is usually free, while the thin tapering extremity, which is often cleft into two, is in contact with the membrane they cover. When the cells exist in several layers, as in the epithelial lining of the trachea, the deeper ones vary much in appearance, and differ greatly from the typical columnar cells.

Where Found.

1. Beginning abruptly about an inch above the cardiac orifice of the stomach, it lines the mucous membrane of that viscus, and that of the alimentary canal as far as the anus, as also the ducts of the glands that open on its surface.

2. It is found in the ducts of all glands, and is frequently called *duct* epithelium on that account.

3. It lines the mucous membrane of the uterus, and is also met with in the deep cells of the epithelial lining of the trachea and oviducts.

3. SPHEROIDAL EPITHELIUM (P. VII. Fig. 29).

These cells are usually spherical in shape, though they may be rendered polygonal by mutual pressure. This substance is usually granular, and they possess a well-marked nucleus, and nucleolus. They have been seen to execute spontaneous movements, and are capable of gliding over one another, and so changing their position without becoming detached.

Where Found.

This form of epithelium is found in all secreting glands, hence it has been called *glandular* or *secreting* epithelium. Because in its typical condition it is round in shape it has been called *spheroidal* epithelium, and on account of the granular appearance its cells possess, it has sometimes received the name of *granular* epithelium.

4. CILIATED EPITHELIUM (P.VII. Fig. 31).

The cells of this variety vary much in form, but they are generally cylindrical, though in some few instances they are spherical in shape. When they are cylindrical they resemble in all their chief characteristics the ordinary columnar cells; their nucleus and nucleoli are well marked, the cell-substance

is finely granular, and they are attached by their pointed extremities to the membrane they cover. Their basal border is surmounted by a tuft of minute cilia or hair-like processes of the protoplasm of the cell. These cilia vary much in number, some cells possessing only two or three, while others possess as many as fifty. The basal border of the cells, where these cilia spring, usually presents a bright appearance. The smaller ends of the cells differ from those of the ordinary columnar cells in that they are almost always bifid. When the ciliated cells are spherical in shape, only that aspect of the cell which forms part of the general epithelial surface is furnished with cilia. These cilia are continually executing a peculiar lashing vibratile movement, which lasts during life, and for some time after death. When a specimen of ciliated epithelium is examined under the microscope these cilia are seen to execute this movement in rapid succession—they all appear to bend, or bow, synchronously, and then partially to recover themselves, only to bend again, and the appearance thus produced has been described as similar to that

produced by the wind when it passes over a field of corn. When, however, their motion is very rapid, and their partial recovery from the preceding wave cannot be observed, their motion possesses the appearance of swiftly running water. The length of the cilia varies from about $\frac{1}{4000}$th to $\frac{1}{2500}$th of an inch. The cause of the movement of the cells is unknown, but it seems to have for its object the propulsion of secreted fluids along the surface towards the orifice of the part they cover, as is the case in the trachea and sinuses of the nose.

Where Found.

1. In the *uterus* from the middle of the neck to the fimbriated extremities of the Fallopian tubes.

2. In the *testicle* from the commencement of the vasa efferentia to the beginning of the vas deferens.

3. Scattered throughout the central canal of the spinal cord, and in the ventricles of the brain.

4. In the respiratory tract and its prolongations. The ciliated epithelium begins a little distance inside the nostril, and then

covering the whole of the membrane of the nose, except that part which is especially devoted to the sense of smell; it is prolonged into the antrum and into the ethmoidal and sphenoidal sinuses, and through the lachrymal duct into the lachrymal sac. From the upper and back part of the nose it passes back over the upper part of the soft palate and pharynx, and is prolonged up the Eustachian tube into the tympanum, the floor of which it lines. The rest of the pharynx is covered by squamous epithelium; but the ciliated epithelium begins again a little above the epiglottis, and lines the larynx, trachea, and the bronchi as far as the pulmonary vesicles. The pulmonary vesicles are lined by a single layer of non-ciliated flattened epithelial cells. The ciliated epithelial cells in the ventricles of the brain and in the tympanum, in the human subject, are of the spheroidal variety.

GENERAL USES OF EPITHELIUM.

One of the chief functions of epithelium is that of *protection:* it is protective in the skin where it covers the delicate nerve endings, or, as has been pointed out, in some cases actu-

ally receiving the terminations of the nerve filaments into the interior of its cells. Besides affording mere mechanical protection it appears to possess the function of converting what otherwise would be a sense of pain into tactile and temperature sensations. In the *horny* layer of the epidermis it is protective in another sense, as here, owing to its non-absorbent power, it prevents the skin absorbing, so long as the epidermis is intact, poisonous or noxious materials. It is also protective in the ciliated form where it propels particles towards the orifices of the body. Epithelium lines also the sensorial surface of the eye, ear, nose, and mouth, and forms the medium by which the various stimuli which affect these organs reach the delicate nerve endings and are conveyed to the brain. Then again, epithelium possesses the function of secretion, that is, of chemically transforming certain materials of the blood. In some cases the substance of the epithelial cells is differentiated into the secretion of the gland they occupy. The cell substance of the epithelial cells of the intestine is, for instance, discharged, by the rupture of their

capsules, as mucus. As stated above, the epithelial cells, while constantly being renewed by the division of the deeper cells, are at the same time being cast off from the free surface.

CHAPTER IX.

BLOOD.

General Characters of the Blood—Its Microscopical Appearances—The Parts of the Blood—Histology of the white and red Corpuscles — Properties and Composition of the Blood—Function of the Blood.

IN the preceding description, the tissues have been considered as belonging either to the active or the passive tissue group. This tissue fills a totally distinct position, and its chief features possess rather a physiological than a histological interest. *Blood* is, histologically, the simplest form of tissue, consisting of cells embedded in a fluid matrix.

Microscopical Appearances (P. VIII. Fig. 32).

When examined under the microscope, in the living vessels, blood is seen to consist of a transparent, colourless fluid known as the *liquor sanguinis*, and a number of minute solid particles suspended in it called the *corpuscles*. These corpuscles are of two kinds, the coloured

and the colourless; or, as they are sometimes, but less properly, called, the red and the white. The coloured corpuscles are nearly spherical in outline; but as most of them possess a shallow depression on both surfaces, they are really biconcave disks.

HISTOLOGY OF THE COLOURED CORPUSCLES.

The coloured corpuscles consist of a highly elastic framework or stroma, the meshes of which are occupied by a semi-fluid colouring matter, which appears to be in physical rather than chemical combination with the corpuscles, and which is readily separated from them by means of reagents. If placed in water, for instance, the colouring matter is dissolved out and the stroma becomes colourless, though at the same time it swells up owing to the imbibition of fluid. This colouring matter is the *hæmoglobin.* The highly elastic nature of the stroma enables the corpuscles to alter their shape on the slightest pressure, and so adapt themselves to the varying size of the vascular channels through which they have to pass, as may be seen when the circulation in the living vessels

is observed in some transparent part, as the web of a frog's foot. The elastic nature of the stroma also enables them readily to recover their original form. Sometimes the corpuscles vary in shape, but these variations are due generally to the changes which take place in the blood after it has been withdrawn from the body, or they may be brought about by the action of reagents.

Thus, when the corpuscles are exposed to the action of water, they at first become flattened and then doubly convex, ultimately becoming globular and much diminished in size. When a dilute solution of chloride of sodium is added to the corpuscles, their surface becomes beset with minute processes, so that they resemble somewhat the fruit of the horse-chestnut in appearance. When the corpuscles are treated with a two per cent solution of tannic acid, some portion of the circumference of the corpuscle appears to give way, and the coloured contents of the corpuscle protrude in a little knob from its surface.

Besides varying in shape, the coloured corpuscles also vary much in size. Even in

the same specimen of blood, corpuscles varying from $\frac{1}{4000}$th to $\frac{1}{28000}$th of an inch in diameter, may be observed; the average size is, however, according to Todd and Bowman, about $\frac{1}{3500}$th of an inch in diameter. The size of the corpuscles also varies greatly in the different species of animals (P. VIII. Fig. 33). The largest corpuscles are met with in the amphibia, that of the *proteus* being $\frac{1}{400}$th of an inch in length and $\frac{1}{727}$th of an inch in breadth, while the smallest are those of the *musk deer*, which are less than $\frac{1}{12000}$th of an inch. The corpuscles of birds, though larger than those met with in the mammalia, do not vary much in size. As regards the corpuscles of mammalia, they are smaller in the quadrupeds than in man, with the exception of the elephant, which possesses the largest corpuscles as yet met with in any mammalian, being $\frac{1}{2700}$th of an inch in diameter.

When the blood is examined while it is circulating, it is seen that in the larger capillaries, and in the small arteries and veins, which are sufficiently large to allow of the passage of several corpuscles abreast,

the coloured corpuscles, while separated from one another, occupy the middle of the vascular channel. When, however, the blood is withdrawn from the vessels, the coloured corpuscles show a great tendency to adhere to one another. They generally cohere by their flattened surfaces; and when a number of them are aggregated together, they give rise to the appearance as of piles or rouleaux of coins, and these piles or columns of corpuscles often unite together to form an irregular network. When thus adherent, the corpuscles will resist, to a great extent, any attempts which may be made to separate them; but if left alone, after a time they separate from one another spontaneously. This tendency of the corpuscles to adhere together is more especially marked in inflammatory blood, and materially hastens the descent of the corpuscles in the plasma, thus facilitating the production of the *buffy coat.*

The number of coloured corpuscles is about five millions to one cubic millimetre. The proportion of coloured corpuscles is increased under any circumstances, which cause a diminution of the fluid part of the

blood. The coloured corpuscles, when seen singly, are of a faint yellow colour; and it is only when they are aggregated together in considerable numbers, that they give rise to the deep red hue which gives the blood its characteristic appearance.

Histology of the Colourless Corpuscles.

The colourless corpuscles are generally spherical in form; but as they are capable of undergoing amœboid movement, their outline is necessarily liable to great variations. They resemble lymph corpuscles and pus cells; and though they vary in size to some extent, they are, as a rule, larger than the coloured corpuscles, their average diameter being about $\frac{1}{2500}$th of an inch. They differ much less in size and appearance in different animals than the coloured corpuscles. They are much less numerous than the coloured corpuscles, the proportion being about two or three colourless to one thousand coloured ones. In venous blood, however, the proportion of colourless to coloured corpuscles is much greater, and this is especially the case in the splenic vein; there being about one colourless cor-

puscle to two thousand coloured ones in the splenic artery, while in the splenic vein the proportion has risen as high as one colourless corpuscle to sixty or seventy coloured ones.

Their numbers vary greatly with the amount and nature of the food taken, and they are said to become more numerous after a meal, especially an albuminous one, and to diminish again on fasting. They have no tendency to adhere to one another, and are specifically lighter than the coloured corpuscle; and this has been assigned as the cause of their remaining in the upper part of the clot during coagulation, while the coloured corpuscles sink to the bottom. They possess the power of taking into their interior foreign particles with which they may come in contact; and this property has been made use of as a means of demonstrating another peculiar property they possess, namely, that of migrating from the vessels into the adjacent textures, for by injecting coloured particles into the blood, which have been taken up by these corpuscles, their presence has been clearly shown in non-vascular tissues, such as

the cornea. The protoplasm forming the body of the colourless corpuscles is traversed by a network of fine fibrils, which forms what is called the *intra-cellular* network, and in the meshes of this network a clear interstitial substance has been observed. These corpuscles usually possess more than one nucleus, which can generally be made apparent by the addition of acetic or other dilute acids. In some cases the protoplasm of the cells is finely granular throughout, while in others the granules are less numerous, though larger and more strongly refractile. These cells possess no definite cell-wall. On the addition of water the amœboid movements of the corpuscles cease, the nuclei coalesce, and the cell ultimately bursts and discharges its contents. Electricity causes them to become spherical and checks their amœboid movement, but this begins again on the cessation of the stimulus.

Properties and Composition of Blood.

The blood is a thick fluid alkaline in reaction, possessing a saltish taste and with a specific gravity, which varies from 1·050 to 1·060, the average being 1·055. It is of a

bright scarlet colour in the arteries, but in the veins it is of a deep purple hue. The fundamental difference between venous and arterial blood consists in the relative proportion of the oxygen and carbonic acid gases contained in each. The proportion of oxygen being greater in arterial than in venous blood. The gases of the blood are oxygen, carbonic acid, and nitrogen. About 50 or 60 volumes of the gases collectively can be obtained from 100 volumes of blood. The average composition of the gas obtained from 100 volumes of blood may be set down as follows:—

	Oxygen.	*Carbonic acid.*	*Nitrogen.*
Arterial blood	20 vols.	39 vols.	1 to 2 vols.
Venous blood	8 to 12 vols.	46 vols.	1 to 2 vols.

(FOSTER.)

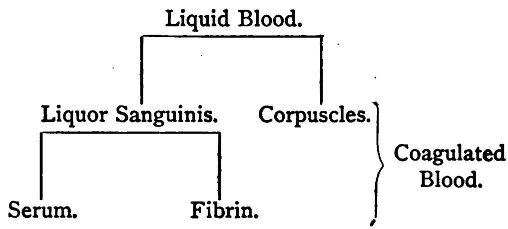
The *temperature* of the blood is generally about 100° F., but it varies considerably in different parts of the body, becoming warmer as it traverses the internal organs, especially the liver, muscles, and the nerve centres, but being cooled somewhat as it passes through the capillaries of the skin. The quantity of water present in the blood

also varies greatly. It is increased when a quantity of fluid is taken, and when the organism is deprived of solid food. It is diminished by exercise and excessive action of the skin and kidneys. The fœtal blood is said to contain less water than the maternal.

Blood has a peculiar odour, and it is said that it is possible to tell the animal from which a particular specimen of recently drawn blood is derived by the distinctive odour it possesses: the well-known odour of the pig and the cat, and the milky odour of the cow, being readily detected in the blood of these animals. When blood is withdrawn from the body it becomes sticky, and exhibits a marked tendency to cling to the vessel in which it is placed. This stage, which is known as the *viscid* stage, lasts from one to three minutes, it then passes into the jelly stage; and during this stage, if the vessel in which it is contained is inverted, and the clot shaken out, it will be seen to have taken a complete mould of the vessel it occupied. This stage lasts from three to eight minutes.

Little beads of moisture now gradually make their appearance on the surface of the clot, and these gradually coalescing the surface of the clot is covered by a thin layer of straw-coloured fluid. The fluid now gradually appears between the sides of the clot and the wall of the vessel, and ultimately between the under surface of the clot and the bottom of the vessel, so that the clot floats in the straw-coloured fluid or serum which has been expressed from it. This last stage, the contraction of the clot and the separation of the serum, may go on for from twenty-four to forty-eight hours after coagulation has first set in. From this brief description it will be seen that, during the process of coagulation, the fluid part of the blood or liquor sanguinis separates into two parts: namely, into a firm solid part the fibrin, and a pale yellowish fluid the serum. When a considerable quantity of fibrin has become developed it undergoes contraction, and, involving the corpuscles in its meshes, it forms the firm part of the clot from which the serum is gradually expressed, as described above. The relation between the constituents of the blood in the liquid and

coagulated states may be represented in the following way:—



It is very difficult to obtain any exact knowledge of the composition of the liquor sanguinis, as it is constantly undergoing changes from the time when it is first withdrawn from the body. The composition of the blood, in 1000 parts, is well given by Ralfe in his *Physiological and Pathological Chemistry*.

Water	795
Solids	205
Fibrin	2
Albumins	70
Hæmoglobin	120
Fatty matters	2
Extractives	3
Inorganic	8

The mean composition of the venous blood

of the horse has been set down by Hoppe-Seyler as follows:—

In 100 *Parts Blood.*

Plasma . .	67·38	Blood Corpuscles	32·62
In 100 *Parts Plasma.*		*In* 100 *Parts Corpuscles.*	
Water . .	90·84	Water	56·50
Solids . .	9·16	Solids	43·50

Relative Proportion of the Solids.		100 *Parts Dry Corpuscles.*	
Fibrin	1·01	Albumins . .	12·55
Serum Albumin	7·76	Hæmoglobin .	86·50
Fats	0·12	Lecithin . .	0·59
Extractives . .	0·40	Cholesterin .	0·36
Soluble Salts .	0·64		
Insoluble Salts.	0·17		

As stated above, the stroma of the coloured corpuscles is pervaded by a coloured material called *hæmoglobin.* It is an albuminous compound, and has the following approximate composition:—

Carbon	54·0
Hydrogen	7·25
Nitrogen	16·25
Oxygen	21·45
Sulphur	0·63
Iron	0·42
	100·00

Hæmoglobin differs from albumin, to which it is allied in chemical composition in its power of crystallising, and in the affinity it has for oxygen and some other gases. The crystals of hæmoglobin, with the exception of those of the squirrel, which are hexagonal, are formed upon the rhombic system, the forms varying in different animals. In man the crystals consist of four-sided prisms, with dihedral summits; in the guinea-pig the crystals are tetrahedral; and in the cat and dog they are needle-shaped, terminated by one plane surface. The crystals of hæmoglobin are soluble in water and in alkaline solutions, but insoluble in alcohol, chloroform, ether, fatty oils, benzole, turpentine, and carbon disulphide. When heated, hæmoglobin solutions coagulate, and the hæmoglobin itself breaks up into *hæmatin* and *globulin*, yielding about 4 per cent of the former to 96 of the latter. The ash of blood shows a great excess of sodium over potassium salts, and of the chlorides over the phosphates, this being the opposite of what is found in muscle ash.

FUNCTIONS OF THE BLOOD.

The blood is an all-pervading tissue, per-

meating every organ and texture of the body. From it the tissues withdraw the materials required for their nutrition, which exist ready formed in the blood, or are capable of production by a process of chemical transformation. Into it also the tissues pass their effete materials, and it forms the medium by which they are conveyed to the organs which are set apart for their elimination. It conveys, through the agency of its coloured corpuscles, the oxygen taken up at the lungs to the tissues of the organism, and in like manner returns to the capillaries of the lungs and skin, there to be expelled, the carbonic acid, which is the outcome of the action of the oxygen on the tissues of the body. The consideration of its physiological uses must be further studied in the physiological text-books.

INDEX.

DESCRIPTION OF PLATES.

PLATE I.

FIG. 1. TRANSVERSE SECTION OF BONE.

a. Haversian canal.

b and *c.* Lacunæ and canaliculi concentrically arranged.

d. Haversian space.

FIG. 2. YELLOW ELASTIC TISSUE.

Showing fibres possessing a well-defined outline anastomosing, and curling up at the ends.

FIG. 3. WHITE FIBROUS TISSUE.

a and *b.* Lines produced by section of the lamellar prolongations of the cells between the bundles of fibres.

FIG. 4. VERTICAL SECTION OF BONE.

a. Haversian canal branching.

b. Lacunæ and canaliculi.

PLATE I.

Fig. 1.

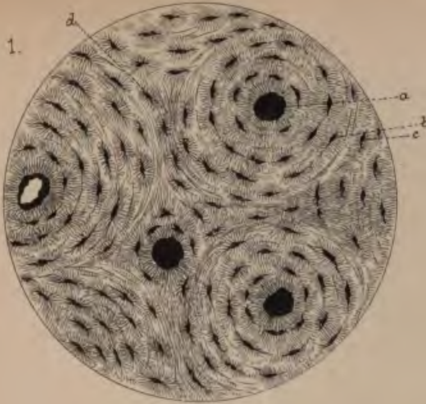


Fig. 2.

Fig. 4.

Fig. 3.

[illegible] del. et lith.

PLATE II.

FIG. 5. SECTION OF HYALINE CARTILAGE.

FIG. 6. VERTICAL SECTION OF TOOTH IN SITU.

a. The enamel.
b. Dentine.
c. Mucous membrane of the gum.
d. Crusta petrosa.
e. Pulp cavity.

FIG. 7. VERTICAL SECTION OF ADULT TOOTH.

a. The enamel.
b. Dentine.
c. Pulp cavity.

PLATE II.

Fig. 5.

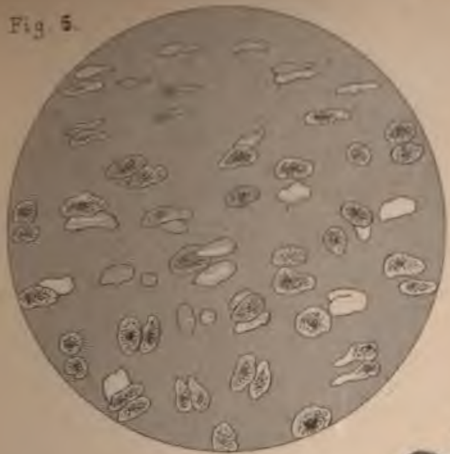


Fig. 6.

Fig. 7.

W. Tivan del. et lith.

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PLATE III.

FIG. 8. DENTINE.
- *a.* Cement.
- *b.* Dentine tubules.

FIG. 9. NODE OF RANVIER.
- *a.* Primitive sheath.
- *b.* White substance of Schwann.
- *c.* Axis cylinder.
- *d.* Intersegmental substance of Ranvier.

FIG. 10. WHITE NERVE FIBRE.
- *a.* Primitive sheath.
- *b.* White substance of Schwann.
- *c.* Nucleus.
- *d.* Protoplasm.
- *e.* Node of Ranvier (after Ranvier).

FIG. 11. ADIPOSE TISSUE.
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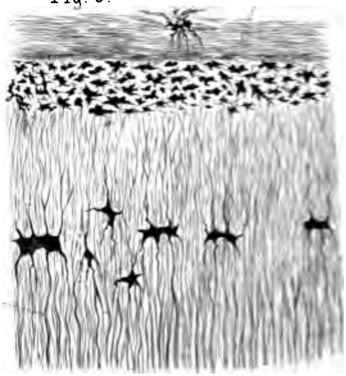
- *b.* Nucleus.
- *c.* Nerve-fibre in section.

Fig. 8.



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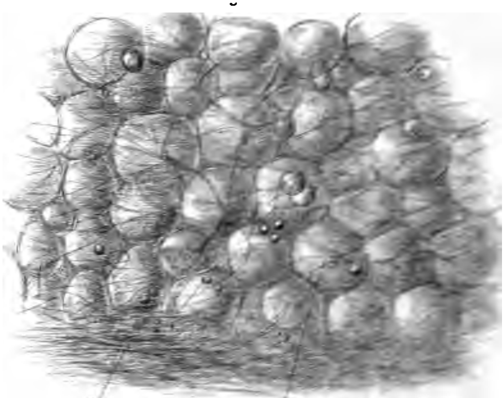

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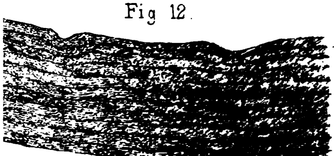

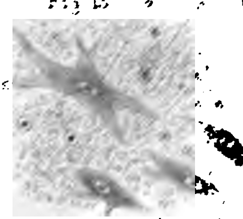

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PLATE IV.

FIG. 14. GANGLION CELL OF A FROG.

a b a. Straight fibre.

b d. Coiled fibre.

c. Small fibre passing to it (after Beale).

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a. Undivided process.

b. Nucleus (Gerlach).

FIG. 16. MULTIPOLAR GANGLION CELL (AFT SCHULTZE).

FIG. 17. COMMUNICATION OF NERVE-FIBRE WI NERVE-CELLS.

b. Nerve-fibre.

a a. Its two divisions communicating with the fi ramifications of the nerve-cells (after Gerlach)

PLATE IV.

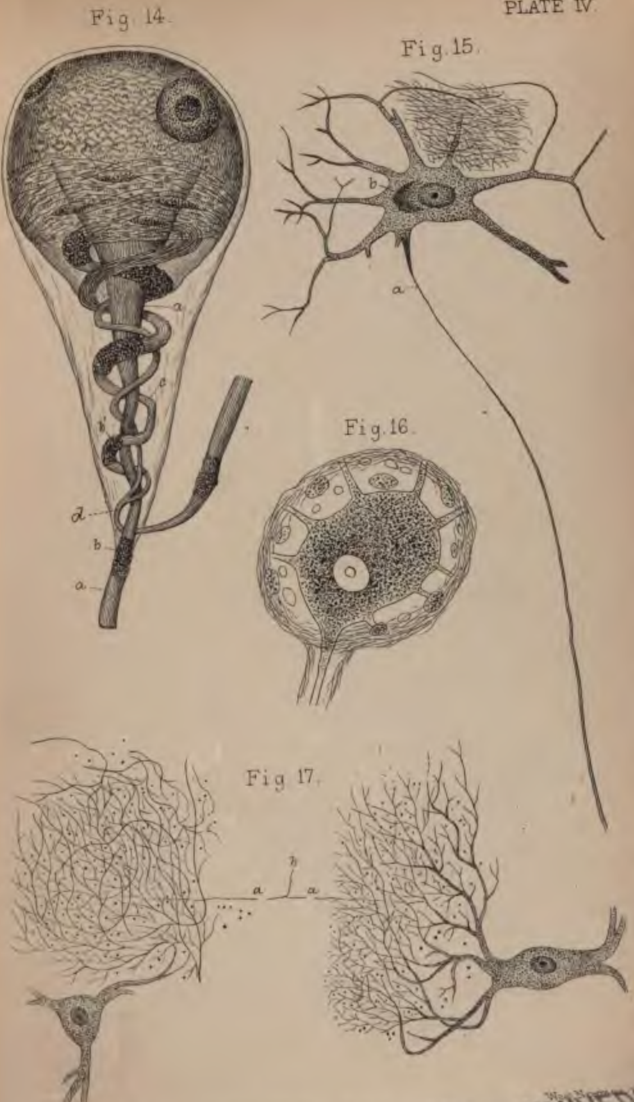

PLATE V.

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FIG. 18. TRANSVERSE SECTION OF MUSCLE.

a. Muscle fibre.

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FIG. 19. TRANSVERSE SECTION OF TOOTH, WITH PULP CAVITY AND DENTINE TUBULES RADIATING FROM IT.

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FIG. 21. STRIATED MUSCLE FIBRE.

PLATE V.

Fig. 18.

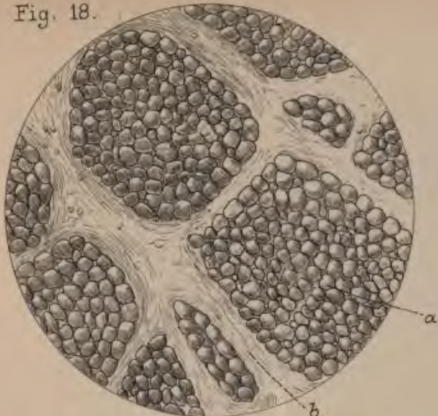

Fig. 19.

Fig. 20.

Fig. 21.

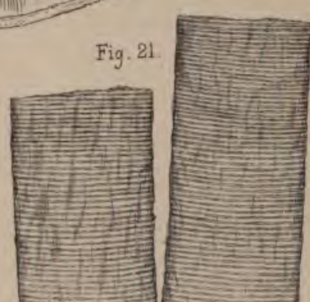

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PLATE VI.

Diagrammatic Representations of the Peripheral Terminations of Nerves.

FIG. 22. MOTORIAL END PLATE.

a. Primitive sheath of the nerve-fibre.
b. White substance.
c. Axis cylinder.
d. Nuclei placed in protoplasmic material.

FIG. 23. TACTILE CORPUSCLE.

a. Primitive sheath.
b. White substance.
c. Axis cylinder ending at the top.
d. Nuclei transversely arranged.
e. Areolar capsule.

FIG. 24. NERVES OF THUMB, WITH PACINIAN BODI[ES] ATTACHED.

FIG. 25. END BULB.

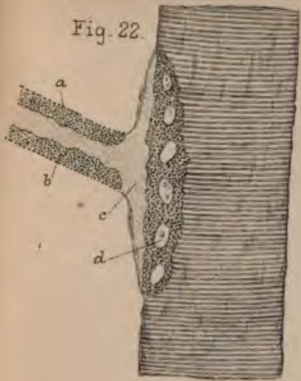
a. Primitive sheath.
b. White substance.
c. Axis cylinder ending in coiled loop.
d. Nuclei vertically arranged.
e. Areolar capsule.

FIG. 26. PACINIAN BODY.

a. Primitive sheath.
b. Its expansion continuous with the lamellæ [of] the capsule.
c. White substance.
d. Axis cylinder ending at far end of the core.
e. Areolar capsule.
F. Lamellæ of inner capsule.
G. Central core.

PLATE VI.

Fig. 22.



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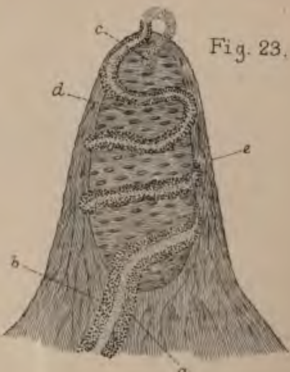

Fig. 24.

Fig. 25.

Fig. 26.

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PLATE VII.

Fig. 27. Squamous Epithelial Cells, from the Mouth.

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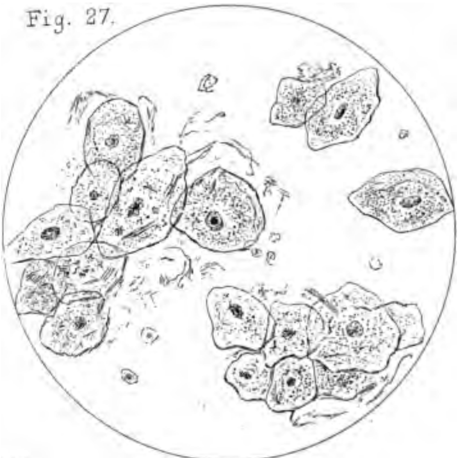
Fig. 27.



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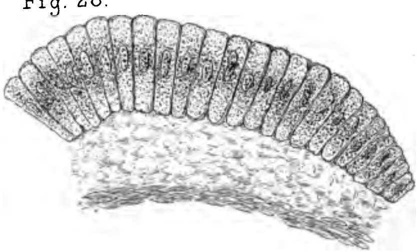

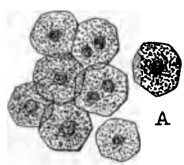

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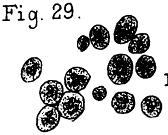

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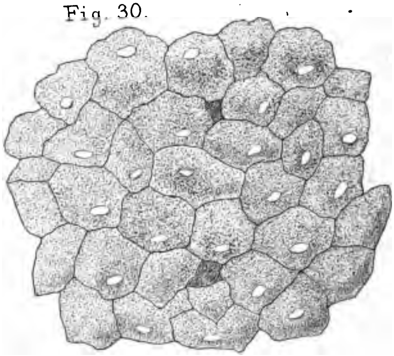

Fig. 31.

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PLATE VIII.

FIG. 32. SPECIMEN OF BLOOD, WITH A SINGLE GRANULAR COLOURLESS CORPUSCLE.

FIG. 33. BLOOD CORPUSCLES OF VARIOUS ANIMALS (AFTER GULLIVER).

PLATE VIII.

Fig. 32.

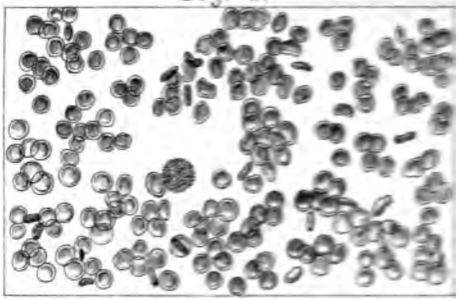
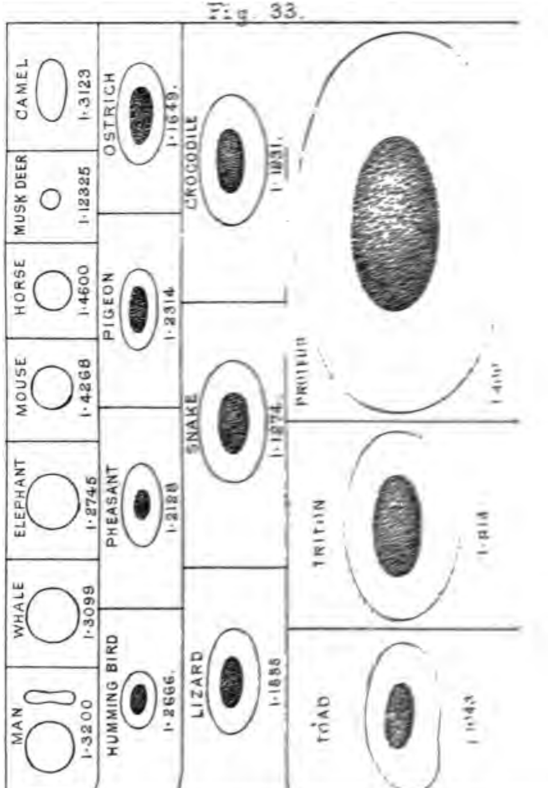


Fig. 33.



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